THE BUILDING OF A TRANSIT LINE

The Massachusetts Bay Transportation Authority's

HAYMARKET - NORTH EXTENSION PROJECT

by **FRANCIS M. KEVILLE**
Director of Construction
Massachusetts Bay Transportation Authority

THIS BOOK IS DEDICATED TO

the Five Construction Workers
who lost their lives
during this immense construction project.

THE AUTHOR WISHES TO ACKNOWLEDGE

the numerous
Agencies, Contractors & Engineering Firms, and Individuals
who participated in the construction
of the

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY'S (MBTA) HAYMARKET - NORTH EXTENSION PROJECT

Including:

Governors of the Commonwealth of Massachusetts
Francis W. Sargent
Michael S. Dukakis

Secretaries of Transportation & Construction
of the Commonwealth
Alan A. Altshuler
Frederick P. Salvucci

Urban Mass Transportation Administration
Massachusetts Legislature
Boston Redevelopment Authority

Past Members
of the Board of Directors
of the Massachusetts Bay Transportation Authority

And the more than 100 Employees of the
Massachusetts Bay Transportation Authority
who were assigned or provided support to the Project.

Special recognition is given to

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major MBTA construction efforts,
and
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THE MBTA'S HAYMARKET - NORTH EXTENSION

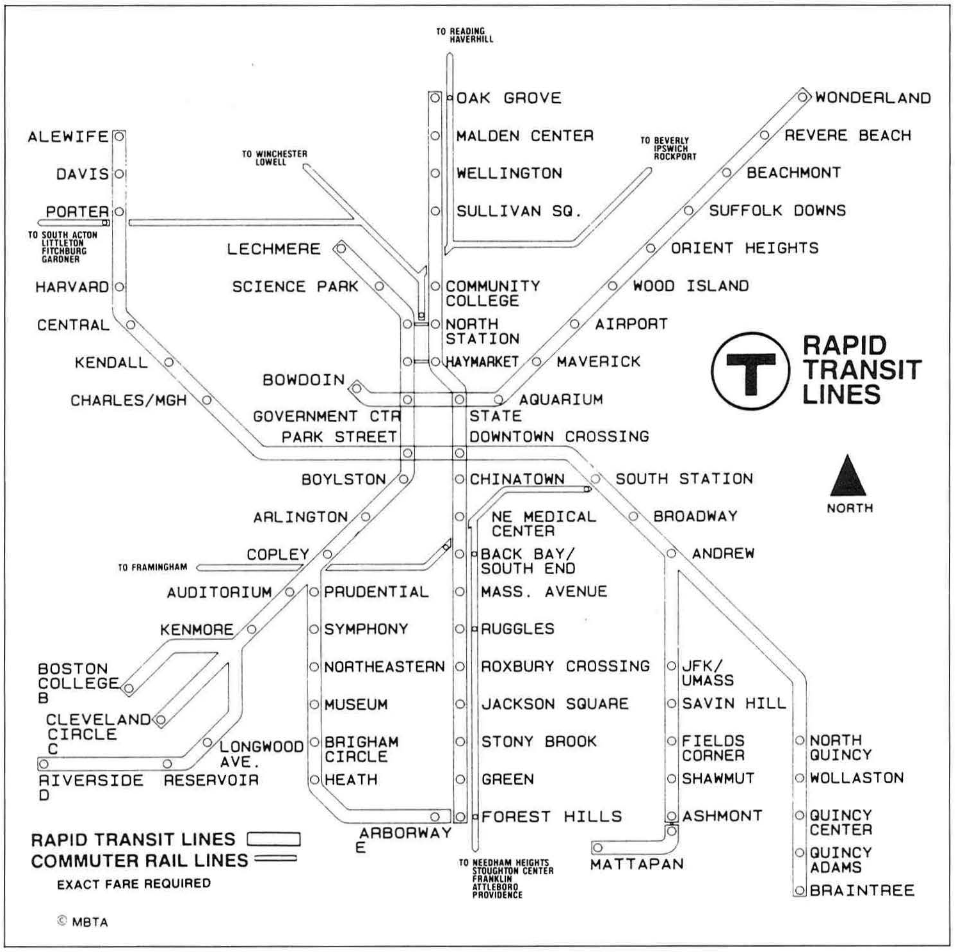
A $161 Million Rapid Transit Extension through the cities of Boston, Somerville, Medford & Malden

by Francis M. Keville
Director of Construction
Massachusetts Bay Transportation Authority

Introduction

The Construction Directorate of the Massachusetts Bay Transportation Authority has achieved national recognition as a leader in transportation construction. Since 1965, MBTA Construction has successfully completed $3 billion in capital improvements projects, including several of the largest and most complicated public works projects ever undertaken in the United States.

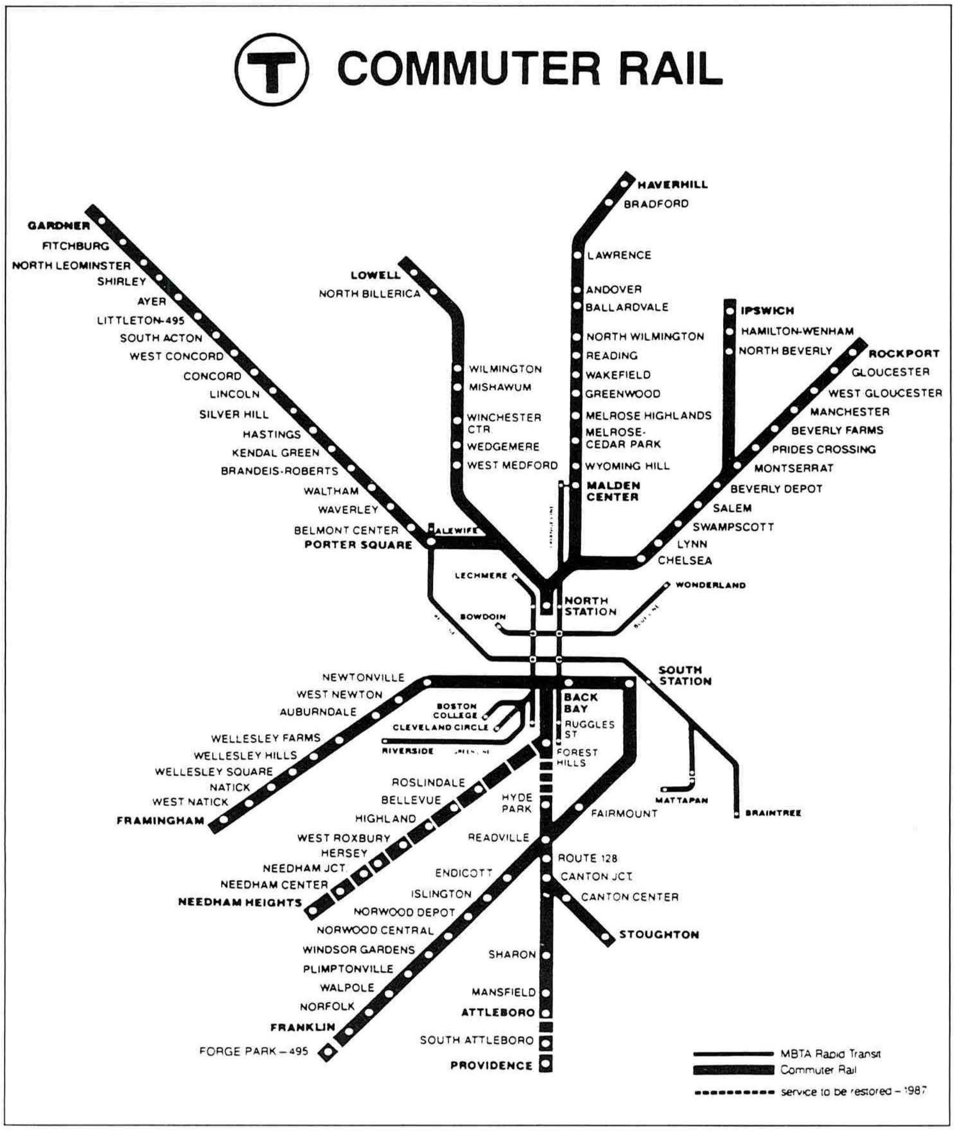
Throughout its history, the MBTA Construction Directorate has tackled immense engineering challenges, accomplished construction efforts under the most difficult of circumstances and locations, and developed the flexibility to work cooperatively with other governmental agencies, business concerns and the public. It has also pioneered the use of numerous innovative and unique construction methods and techniques, many of which have been—and continue to be—adopted by other public works agencies for use in major projects throughout the country.



The MBTA has received most of this attention as a result of its major Red Line Northwest Extension and Southwest Corridor Projects. However, another significant rapid transit project, prior to these undertakings, provided a training ground and experience for the MBTA Construction Directorate's later successes. This project, the **Haymarket-North Extension**, was instrumental in setting the pace for the MBTA's record of capability and accomplishment. Today, it is available as a valuable resource to the MBTA and other public works agencies in planning major construction efforts for the future.

Commencing in September of 1966 and completed in 1977, the Haymarket-North Extension was recognized, during this time, as the most complicated, complex transit engineering work ever undertaken in the United States. Approximately 5.9 miles in length, this Extension of the Orange Line from Haymarket Station in downtown Boston, through the cities of Somerville, Medford and Malden, to a terminus at the Malden/Melrose line passed through a variety of geographic conditions, in close proximity to numerous existing highway and railroad bridge structures, and interfaced at several points with active railroad lines. It included the construction of a sub-aqueous tunnel, numerous bridges, underpasses and overpasses, as well as the underpinning and strengthening of buildings, existing highway and bridge structures and required provisions for constructing through tidelands and other environmentally sensitive areas. In addition, the Project included the demolition of the former elevated Orange Line structure after the completion of the Extension's construction. This included all structures, including five stations, along the old line from Haymarket Square to Everett.

All of these factors required extensive engineering and design planning and, in many cases, redesign to accommodate existing conditions. Throughout the project, close coordination was maintained between the MBTA and a host of public agencies in the Metropolitan Boston Area, in addition to the Boston & Maine Railroad and the Penn Central Railroad. Drawings, specifications and plans required extensive reworking to meet the needs and desires of all parties involved, before construction could begin and throughout its progress.

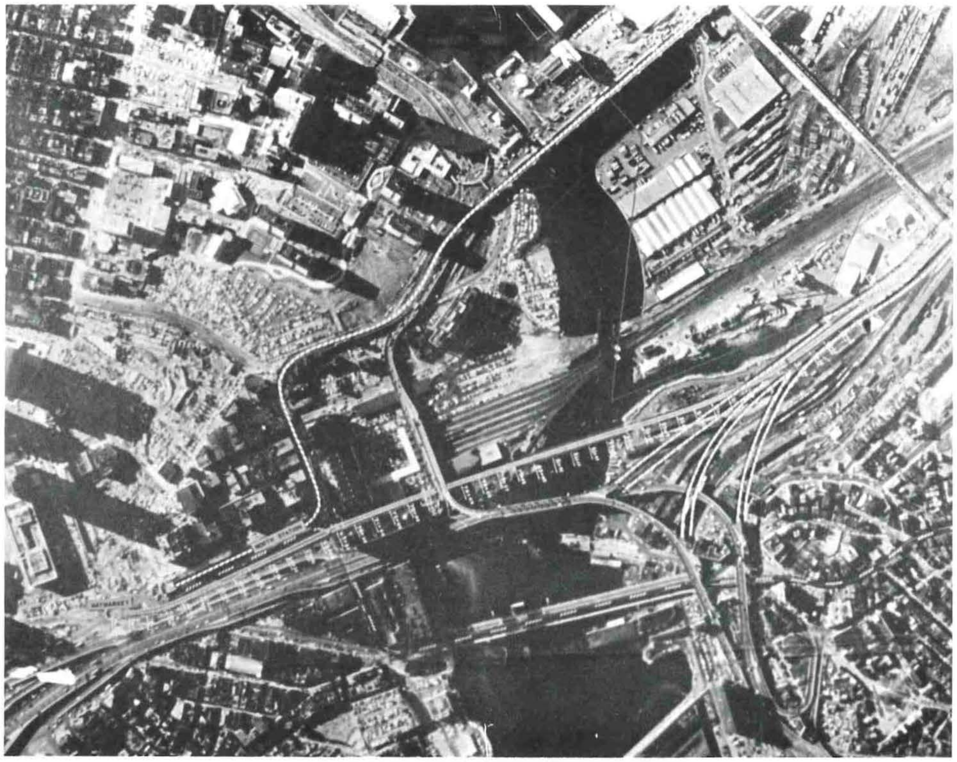


Description of the Haymarket-North Extension

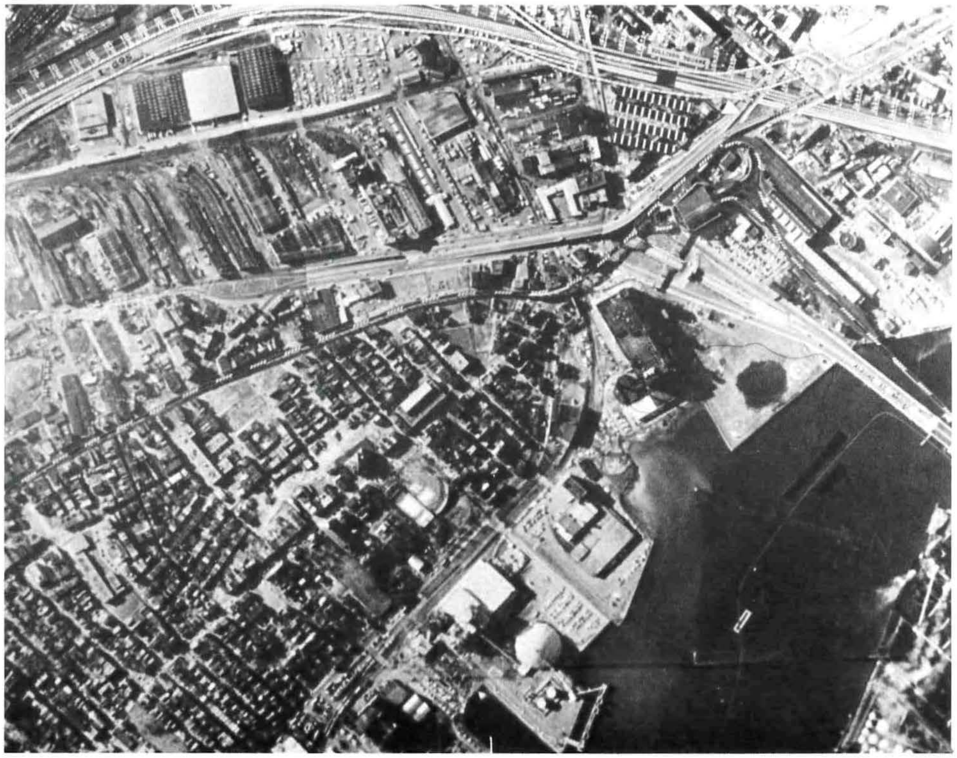
The Extension from Haymarket Station to the Malden/Melrose line was divided into four construction areas:

Area I: The first section, 4,520 feet in length, consisted of a 2-track tunnel from Haymarket Station to a point just south of Prison Point Bridge in Charlestown. It included the new North Sation and the installation of a prefabricated steel tunnel under the Charles River.

Area II: The second section was approximately 6,000 feet in length, extending from the end of the new tunnel to a point near the Charlestown/Somerville boundary along the Reading Branch of the Boston & Maine Railroad right-of-way. This section was constructed directly below the elevated highway structure (I-93), and included two new stations, Community College Station and Sullivan Square Station.



*Alignment from **Haymarket Square to Community College** including the tunnel under the Charles River. Also shown is the former Orange Line alignment, from North Station over the Charlestown Bridge, and into Charlestown.*



*Alignment from **Community College to Sullivan Square and into Somerville,** running under I-93. The former Orange Line alignment is shown through Charlestown and Somerville and onto the bridge crossing the Mystic River.*

The Extension in Area II was constructed on existing ground level except for a 1,500′ viaduct over the Mystic Division tracks of the Boston & Maine Railroad.

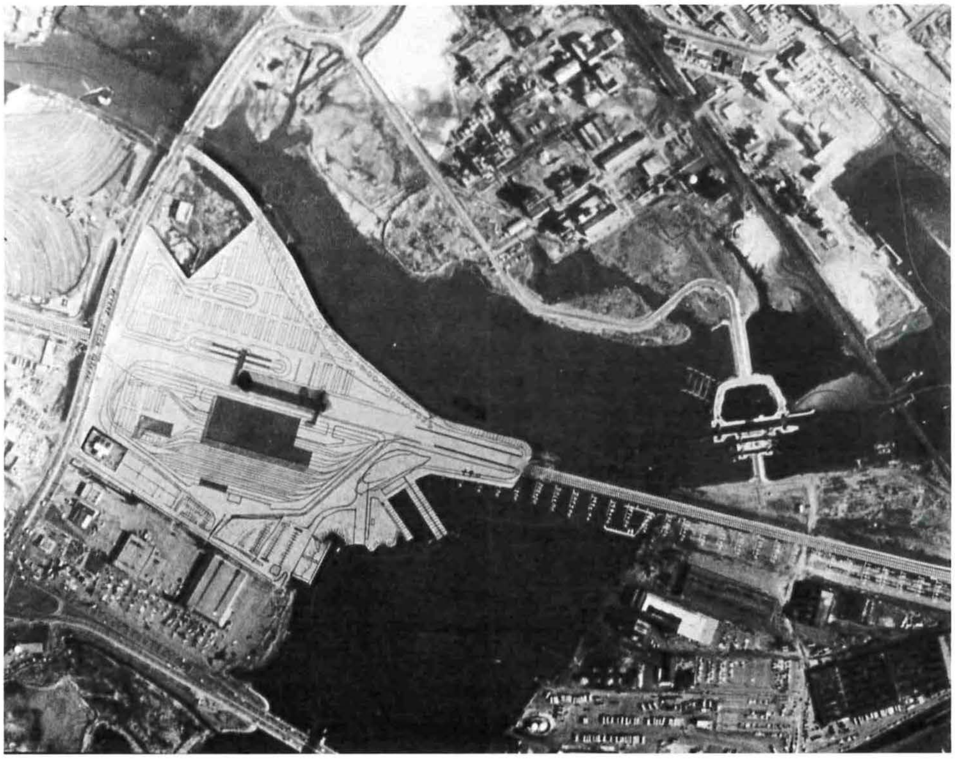
Area III: The third section was approximately 6,700 feet in length, extending from the Charlestown/Somerville boundary to the northerly side of the Revere Beach Parkway in Medford. From the Somerville boundary to the Mystic River, the Extension was constructed at existing grade, then passed over the Mystic River on a new bridge (Edward Dana Bridge), and returned to grade again as it entered the Wellington Station, located on the easterly side of Wellington Circle and south of the Revere Beach Parkway.

The Wellington Complex included the construction of a new Wellington Station with a 1,000 car parking lot and a major yard facility, consisting of rapid transit maintenance repair shops, train storage yard, signal tower, and power substation.

Area IV: This section was approximately 14,000 feet in length, beginning at the northerly side of the Revere Beach Parkway, continuing through Medford and Malden, to the Oak Grove area near the Malden/Medford line.

Through Medford, the Extension was constructed on existing grade except for an underpass section, approximately 1,350 feet in length, where the Extension passed under the Medford Branch of the Boston & Maine Railroad. Proceeding northerly through the underpass, the Extension passed over Medford, Adams, Charles and Pleasant Streets on newly constructed bridges. A new bridge was constructed for the relocated Route 60 highway near Malden Center.

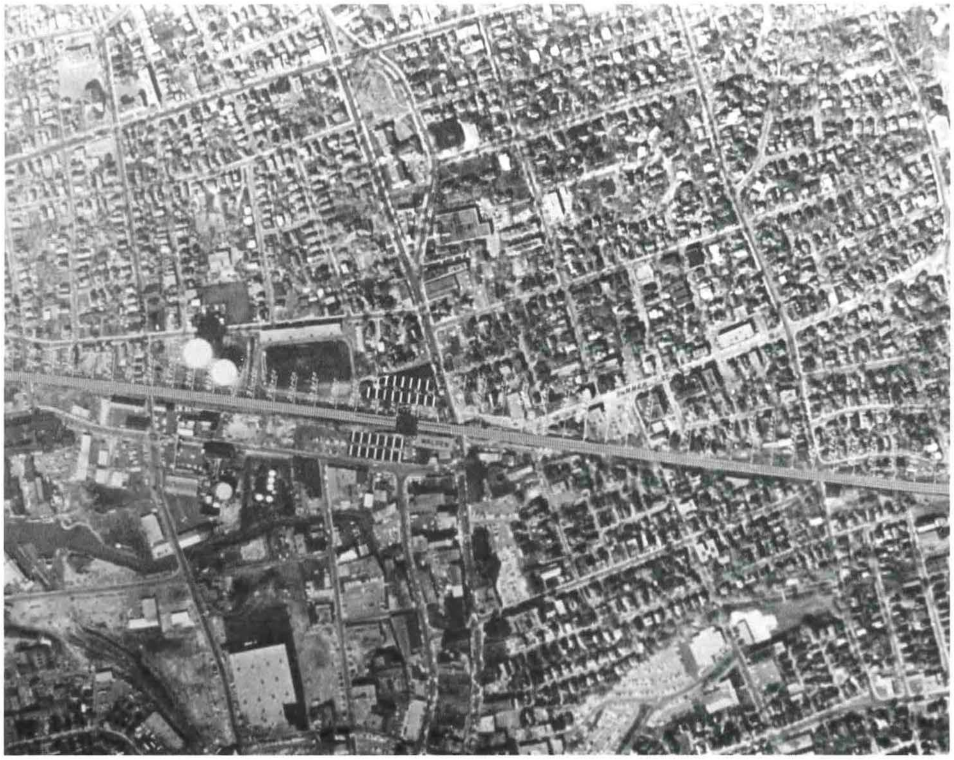
The Extension's new Malden Center Station was constructed at the intersection of Pleasant and Commercial Streets in the area of the new Malden Government Center, west of Malden Square.



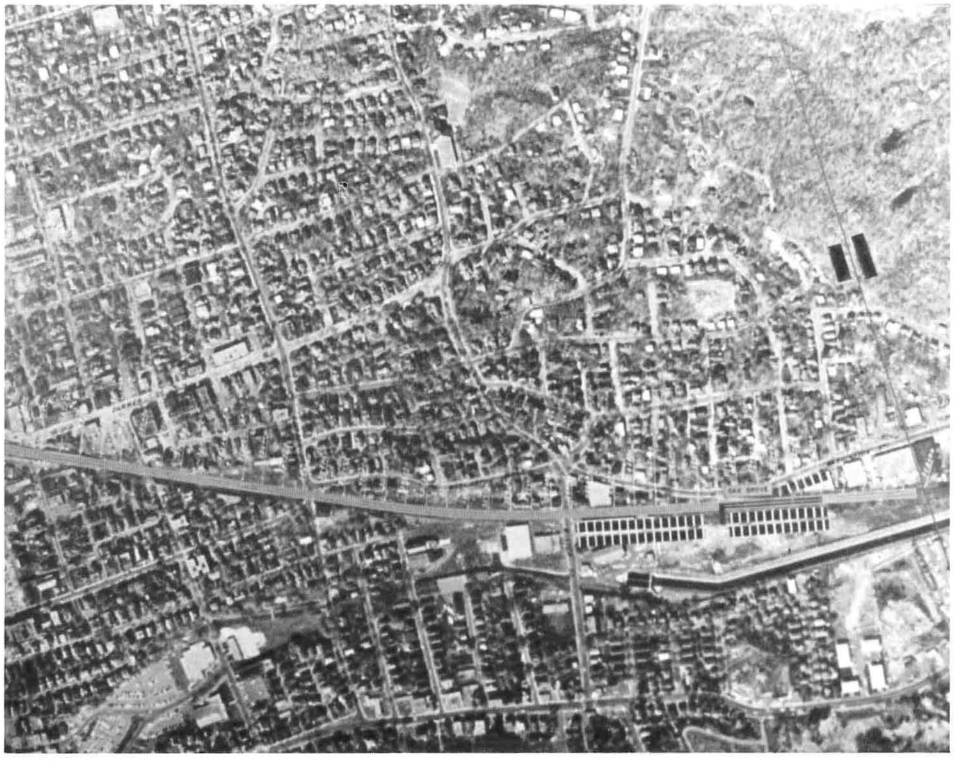
*Alignment from the **Boston/Somerville Boundary** to the northerly side of the **Revere Beach Parkway**, over the **Edward Dana Bridge** and onto **the Wellington Complex.***

North of Malden Center Station, the Extension passed under existing bridges at Mountain Avenue and Clifton Street, continuing north to the Oak Grove area at Winter Street, where a new overpass was constructed to eliminate the existing grade crossing on the railroad track. The Oak Grove Station was constructed immediately north of Winter Street, approximately 1,300 feet south of the Malden/Melrose line.

*Alignment through **Medford into Malden.***



Alignment through ***Malden****, showing the new* ***Malden Center Station.***



Final section of the alignment to ***Oak Grove Station at the Malden/Melrose Line.***

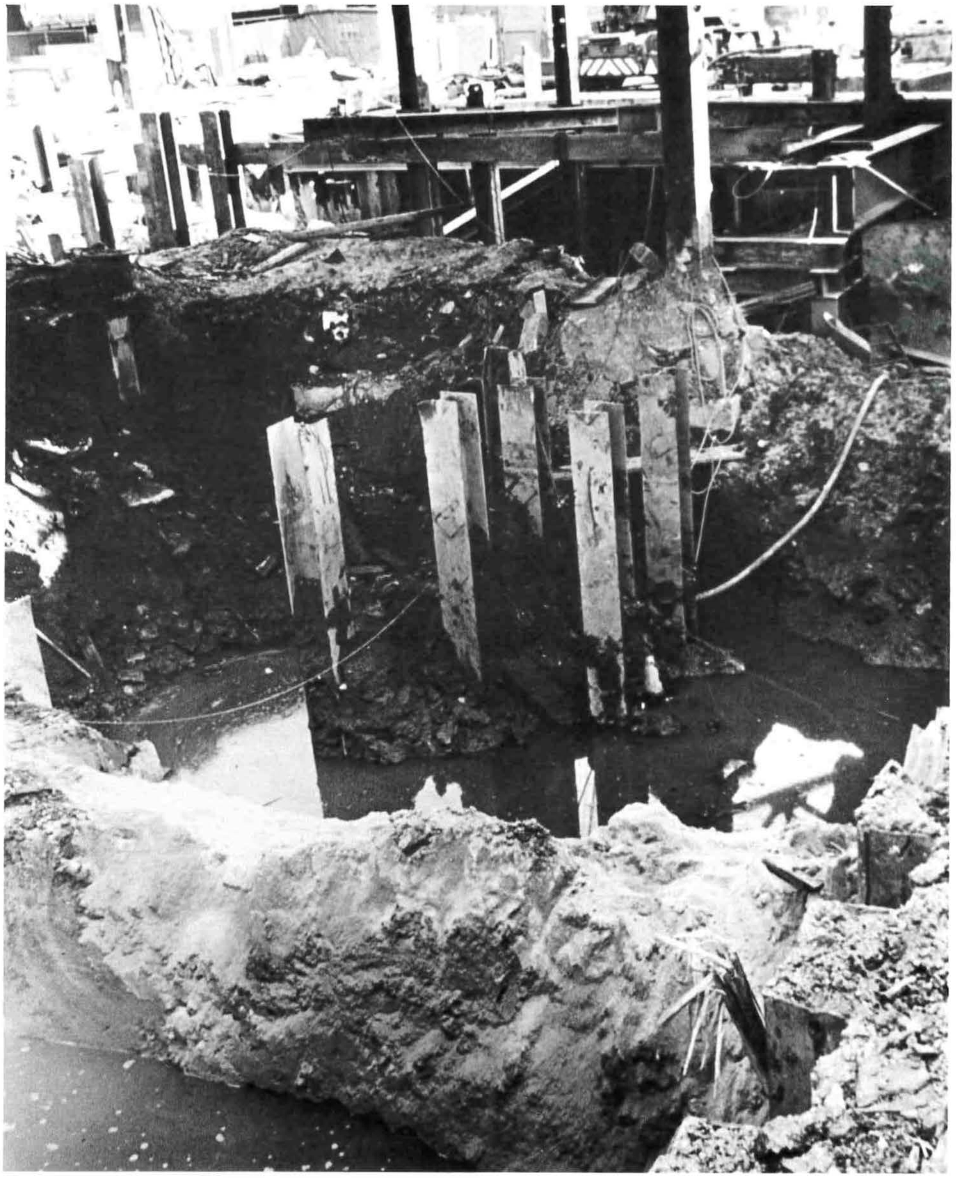
Construction of the Haymarket-North Extension

On September 22, 1966, special groundbreaking ceremonies were held to start this long-awaited Project and work commenced on the first contract. It was completed on March 8, 1971.

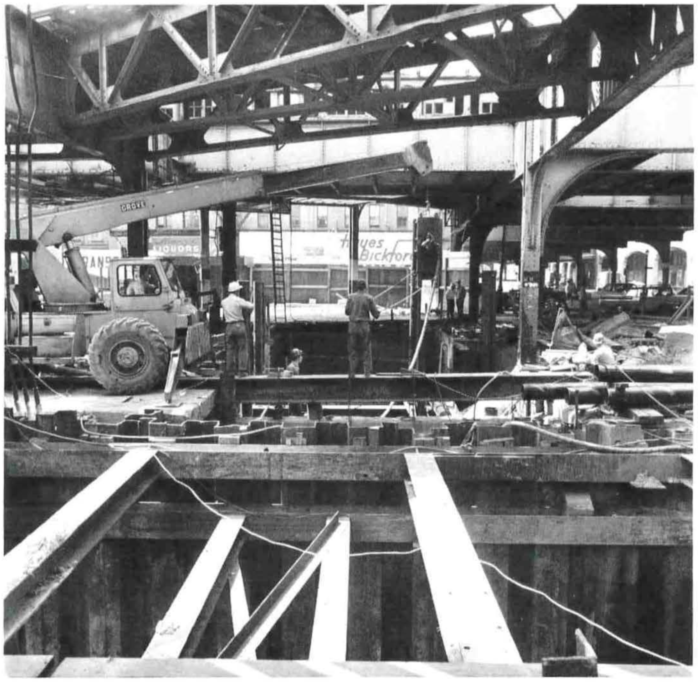
The cut-and-cover tunnel section started at the northerly end of Haymarket Station in Haymarket Square. Being near the operating tracks, the contractor was required to perform 90% of the demolition, underpinning and supporting of the operating track structure between the hours of 1:00 a.m. and 5:00 a.m.

The subway section in Haverhill Street was complicated by the required underpinning and supporting of the existing MBTA Orange Line tracks, track power substation and nine columns of the elevated Orange Line tracks at North Station.

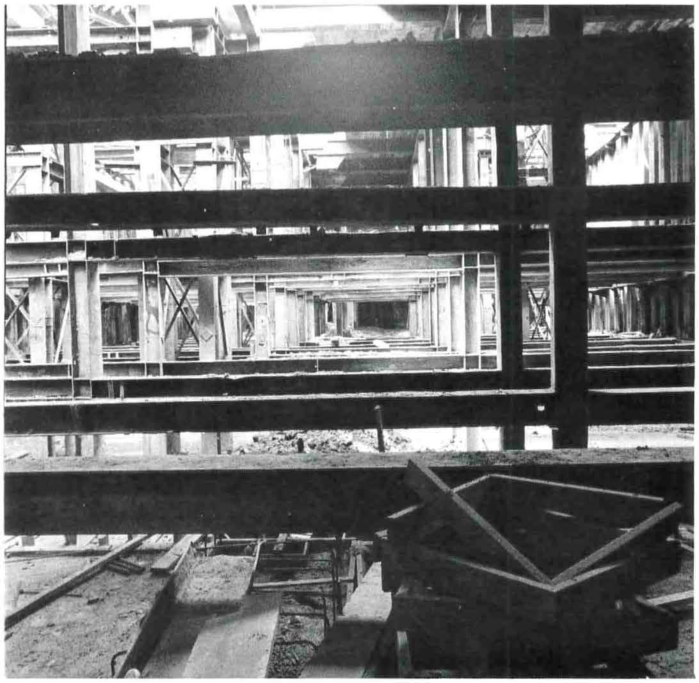
It was also necessary to relocate the City of Boston's combination sewer/drain, which included a twin syphon, under the subway, and connect it to a new 102″ R.C. sewer pipe that was installed under the Mass. DPW's Central Artery (I-93). There was limited head room for this installation.



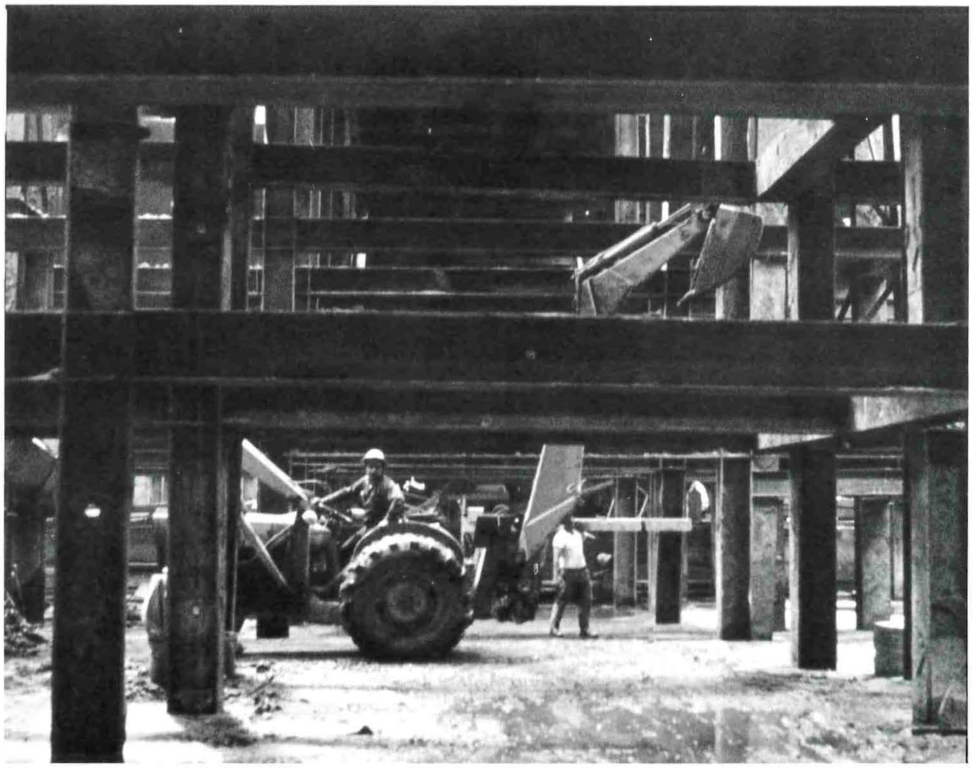
***North Station** was constructed in the tunnel under Haverhill Street at the intersection of Causeway Street. Pictured are some of the support piles for the existing MBTA Orange Line structure.*



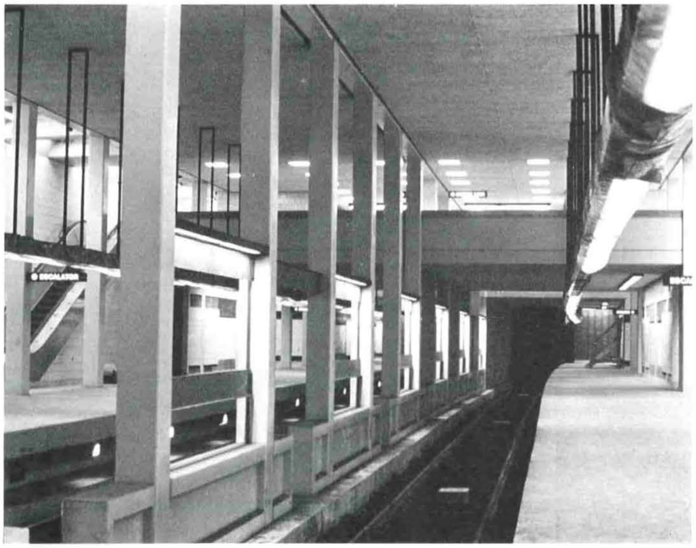
Dockworkers are shown **driving steel sheet piles** in the station's escalator trench on the South side of Causeway Street.



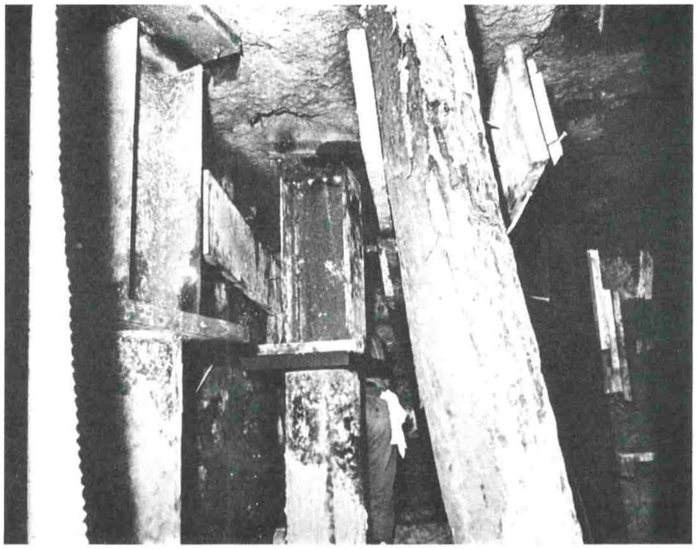
A view, looking north, of soldier beams and trench bracing for the support system for **North Station** area.



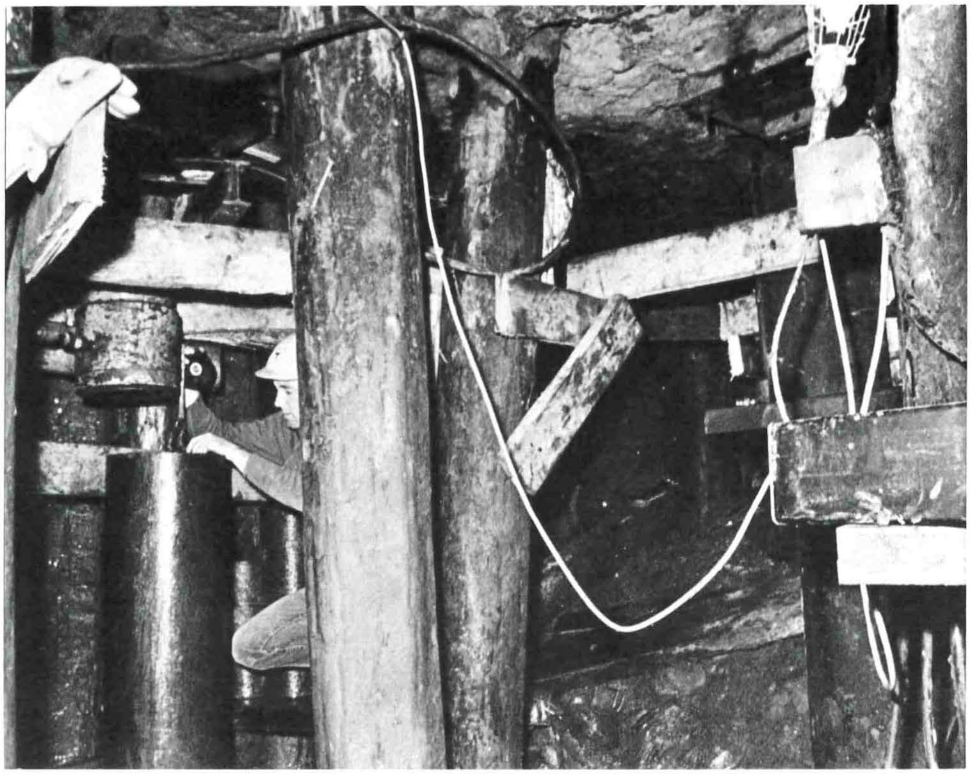
The mezzanine for **North Station**, constructed 14 feet below street level, was connected by escalators and stairways to the station's platforms, 27 feet below street level. Shown is construction activity beneath and amidst the station's steel support system.



*A view of the train platforms at the **completed North Station**. The mezzanine is located to the rear and above.*



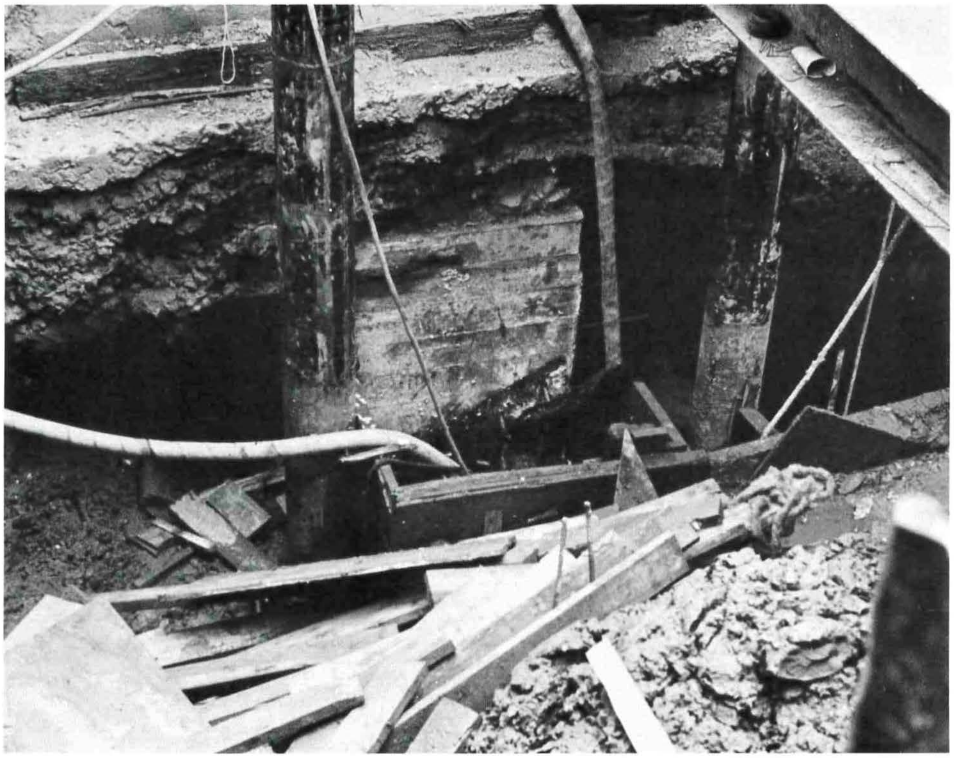
*Excavation in the North Station area required the **underpinning** of the 13-story Industrial Building and Boston Garden Complex. A total of 155 steel piles, as shown, were installed to provide support. The installation was accomplished by jacking six-foot sections of steel pipe down to a bearing capacity of 100 tons.*



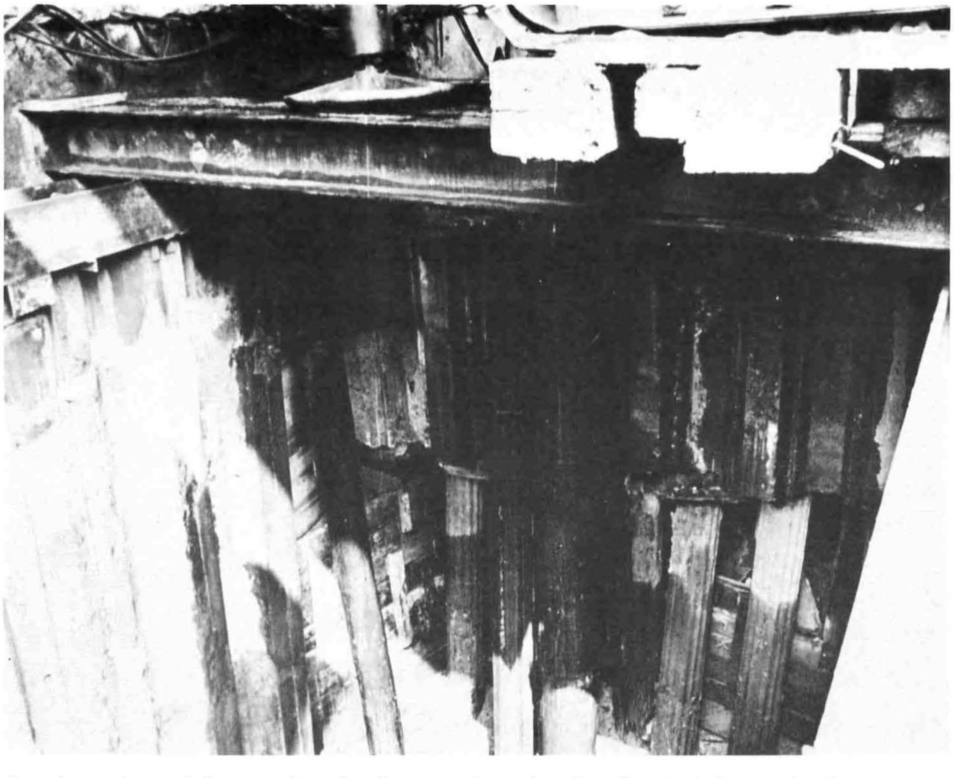
***Construction worker**, positioning sections of pipe behind the pile in the center here, appears tiny in contrast to the massive piles surrounding him. The piles ranged from 40 to 65 feet in length.*

*View of the **existing simplex concrete piles** supporting the Boston Garden, which had to be underpinned due to MBTA construction.*

*The contractor referred to the Causeway Street area, shown here, as a **"bucket of worms"** because of the number of utility lines that had to be supported or relocated before construction could commence.*



Underpinning also was required to support the ***footings for the Central Artery****. This was accomplished by driving caissons on the north and south sides of the footings and installing needle beams between the existing pipe piles.*



Another view of the ***underpinning system*** *for the Central Artery footings.*

The subway section at the North End of Haverhill Street included changes to provide for the new North Station. From this point, construction proceeded under Causeway Street. The contractor described this section as a "bucket of worms" as he was required to install a cut-off wall across the street and relocate and support a variety of existing utility lines. These included gas, water, electric, steam, sewer, oil, 115 KV oil-filled electric lines, AC & DC power lines for the MBTA and Boston and Maine, as well as other lines for surface drainage and service for Western Union, the Telephone Company, U.S. Postal Service and Police and Fire Departments.

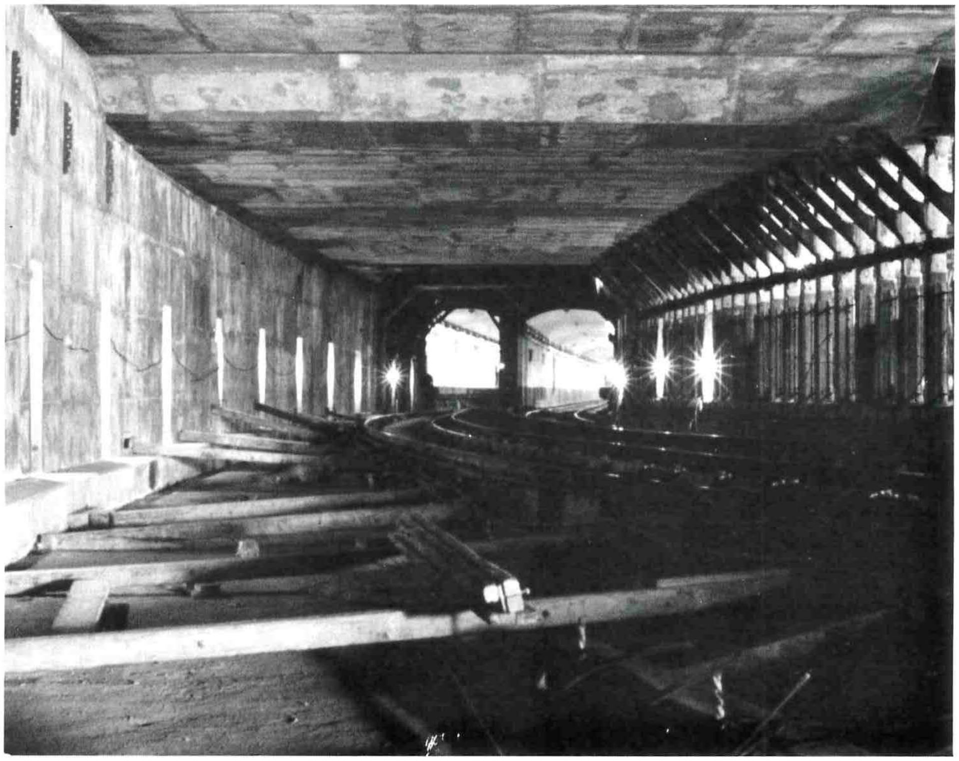
Because the tunnel structure was built under Accolon Way and within three (3) feet of the existing 13-story Industrial Building and the Boston Garden, it was necessary to underpin each building. This underpinning procedure involved digging jacking pits under the pile caps of the buildings and jacking six-foot sections of steel pipe down to a bearing capacity of 100 tons and filling each with high-strength concrete. Each pile had a special pile tip installed, and had to be founded a minimum of three (3) feet below the bottom of the tunnel structure.

In total, the contractor installed 155 piles, from 45 to 65 feet, under these buildings and load tested each pile to double the design load for four hours each.

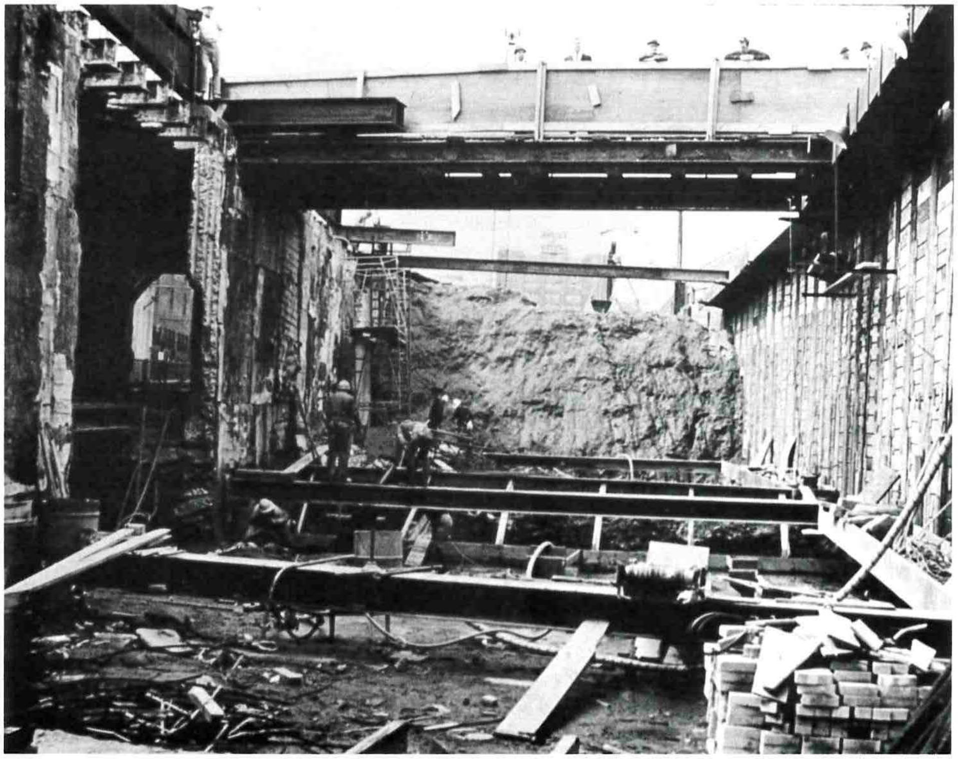
The second major task consisted of underpinning the Central Artery footing (Bent F-4).

The Mass. Department of Public Works (MDPW) advised the Authority that the bent would require underpinning as the bottom of the tunnel construction was adjacent to the pile tips of the Central Artery footings. This required a complete design of a support structure, which had to be approved by the MDPW.

Several design alternatives were presented and the final approved design consisted of a five (5) foot deep steel truss, constructed under the footing of the Bent F-4, and supported on caissons driven approximately 12 feet into solid rock. This construction was authorized by a change order in the amount of $1,140,000 and required a 16-month extension to the contract time.

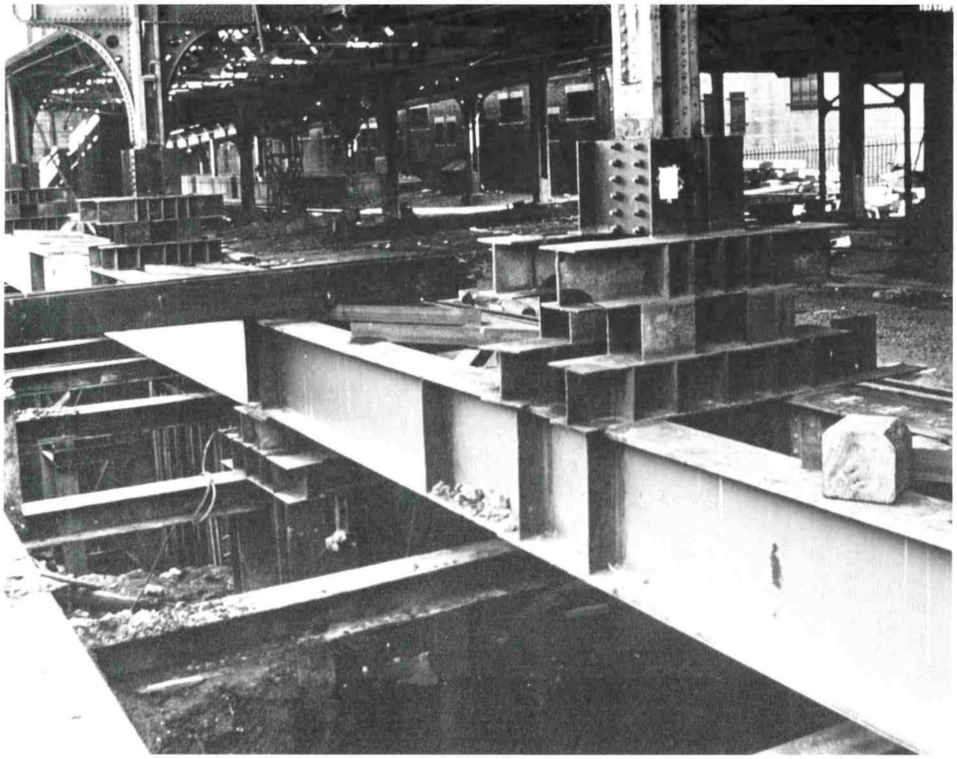


A view of the ***tunnel section beneath Haverhill Street****, with Haymarket Station in the background. At left is the point at which the connector, between the old and new lines, was constructed. At right are columns that provided support for the roof and existing track during construction.*

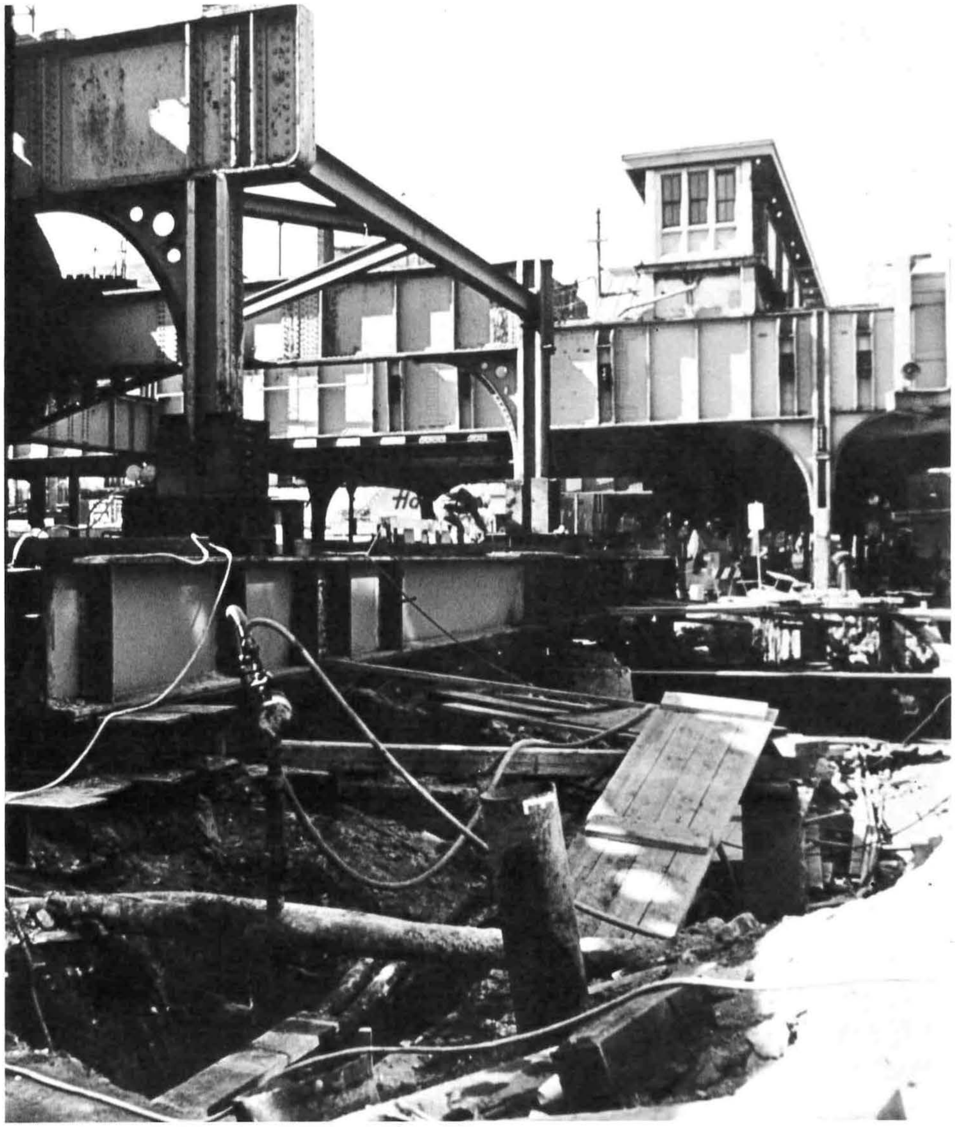


A view of ***construction of the connector*** *beneath Haverhill Street, with sidewalk superintendents looking on from above.*

Service for the Orange Line *was continued throughout construction, as shown in this view of activity in the Haymarket Station area.*

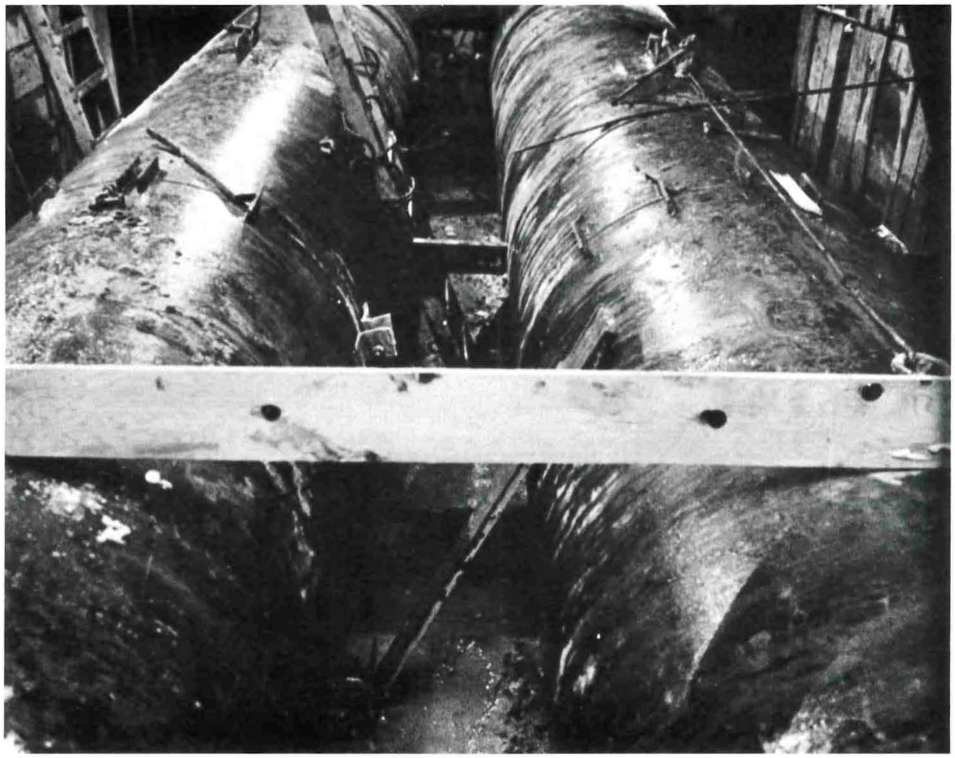


Construction beneath Haverhill Street required the ***underpinning and support of the existing MBTA Orange Line structure****, including the ramps, sub-station and nine el columns at North Station. A section of the support system, consisting of steel piles and bracing, is shown.*

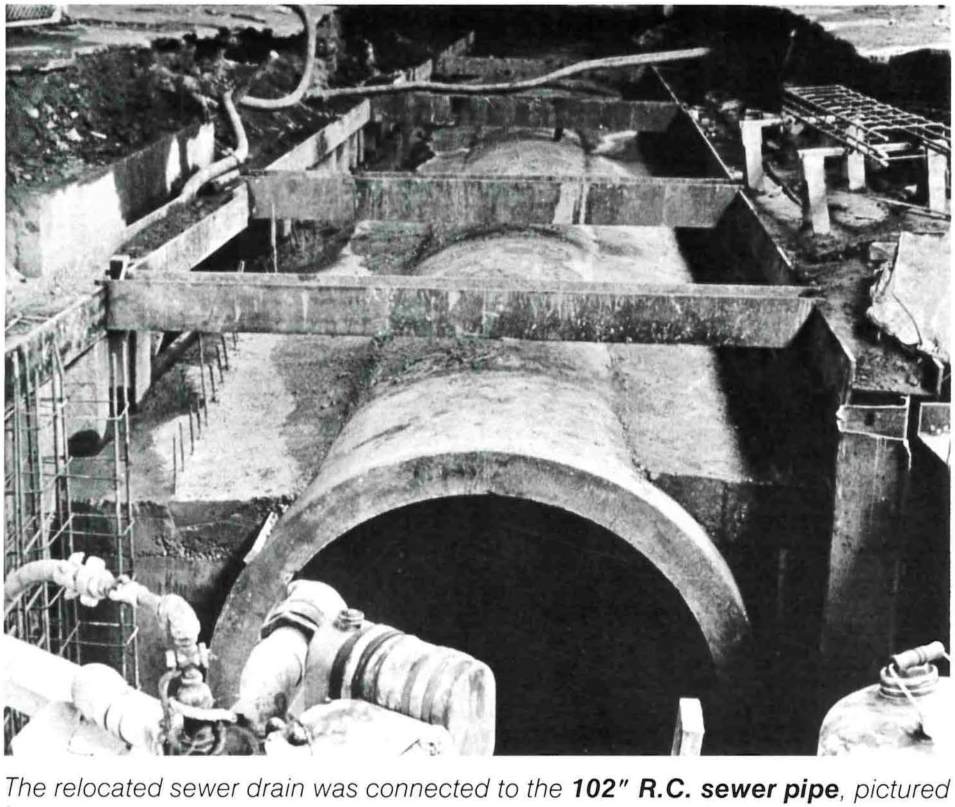


Another view of required under-pinning and support activity *at North Station.*

Close-up view of the maze of piles, *which had to be removed at North Station.*



Shown is the City of Boston's ***twin syphon****, relocated for Haymarket-North construction in the North Station area.*



The relocated sewer drain was connected to the ***102" R.C. sewer pipe****, pictured here.*

At the north end of Accolon Way and on each side of the Charles River, two transition sections were constructed between the cut-and-cover subway section and the prefabricated tunnel sections under the river.

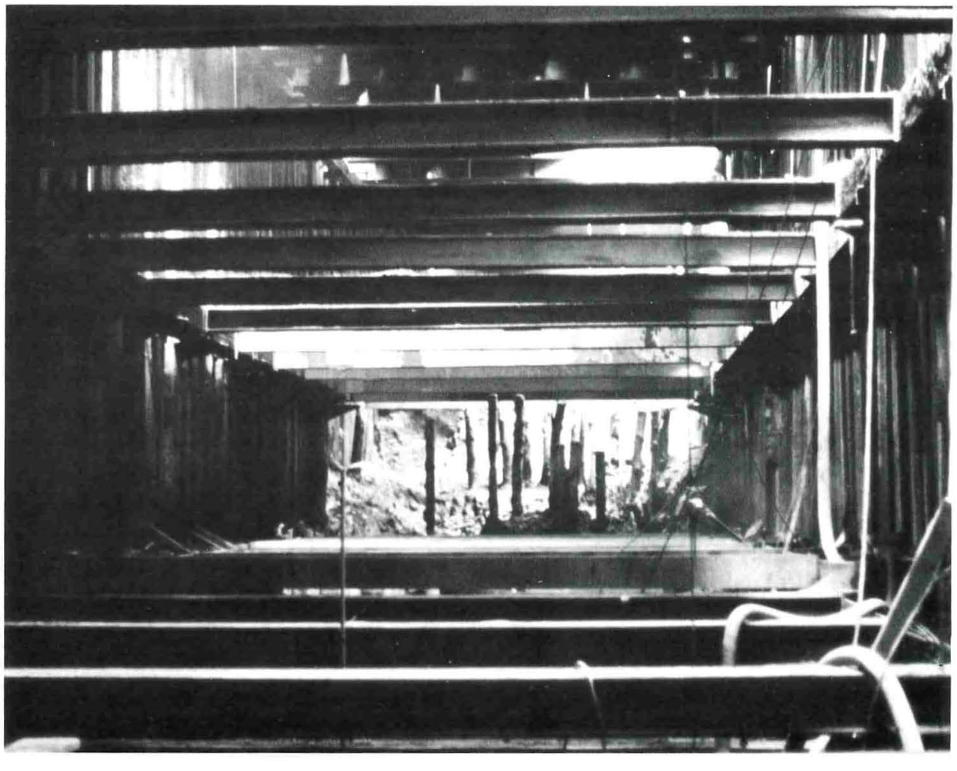
Another major problem associated with this contract was the determination of the best means of crossing the Charles River. Several alternatives were considered, including the construction of a bridge over the river from a point near the rear of Boston Garden. This concept, however, was rejected, partially, because a bridge would conflict with plans to extend Interstate 93 from the Boston & Maine Railroad Yards in Charlestown to the North of Boston.

Following a consideration of all factors involved, it was determined that a tunnel would provide the best option. The question then centered on the method of tunnel construction, and three possible choices were considered.

A bird's eye view of ***Haverhill Street****, looking from the Anelex Building at 150 Causeway Street.*

The first option was to construct a conventional, shield-driven, compressed air tunnel. However, this was discarded because of the depth of the Charles River at the point of crossing and the restrictive track grades of the transit system. Specifically, there would not have been enough cover available to adequately restrain the compressed air beneath the river bed, which could cause the air pressure to rupture the blanket of mud, silt and clay on the river bottom, causing loss of the heading.

The second option was to construct a cast-in-place tunnel, requiring the construction of massive cofferdams. This would restrict the Charles River, which had to be maintained for navigation at all times, to half its width at a time. After construction of one half of the tunnel in the river, the cofferdams would then have to be relocated to the other half of the river. This would have allowed the tunnel to be constructed in the "dry" but would have been costly and time-consuming.



Timber piles*, like these pictured beneath Accolon Way, were installed and later removed during excavation for the construction of transition sections between the subway and the tunnel under the Charles River.*

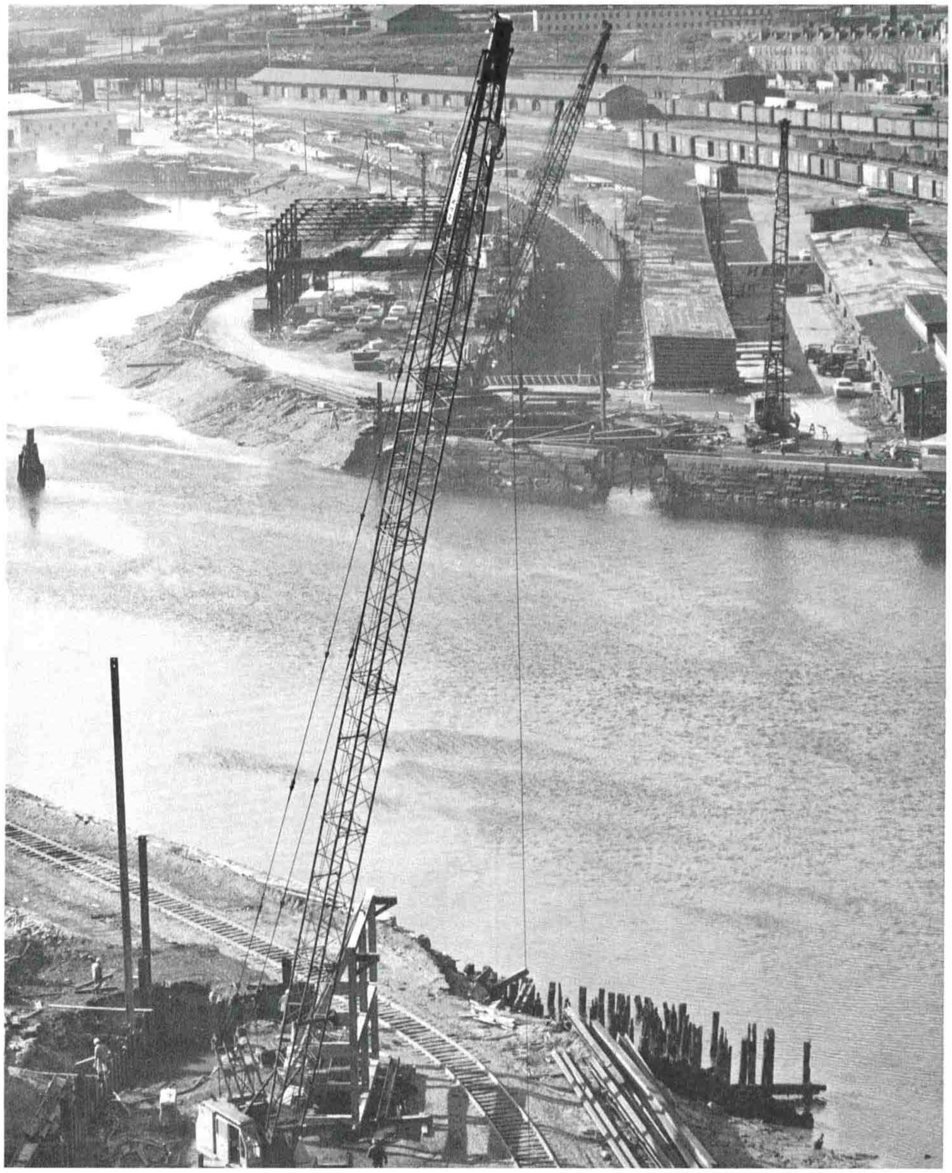
The third option was to install prefabricated tube sections which would be sunk in place. This would require only a single large cofferdam to be constructed on the north and the south sides of the river. Further, it would minimize the area that would have to be dewatered for the purpose of constructing a transition section, which would dovetail the conventional cut-and-cover dry land tunnel sections of the subway structure with the sunken tube sections.

Once the options were examined and rated for feasibility, a decision was made to leave the final determination to the contractors participating in the bid process. Construction plans and specifications were prepared for advertisement to the various and interested contractors offering the cast-in-place method and, as an option, the prefabricated sunken tube method of crossing the river. This provided the contractors with the opportunity to assess the project and use their professional judgment to determine which of the two methods would be better from the standpoint of construction and profit.

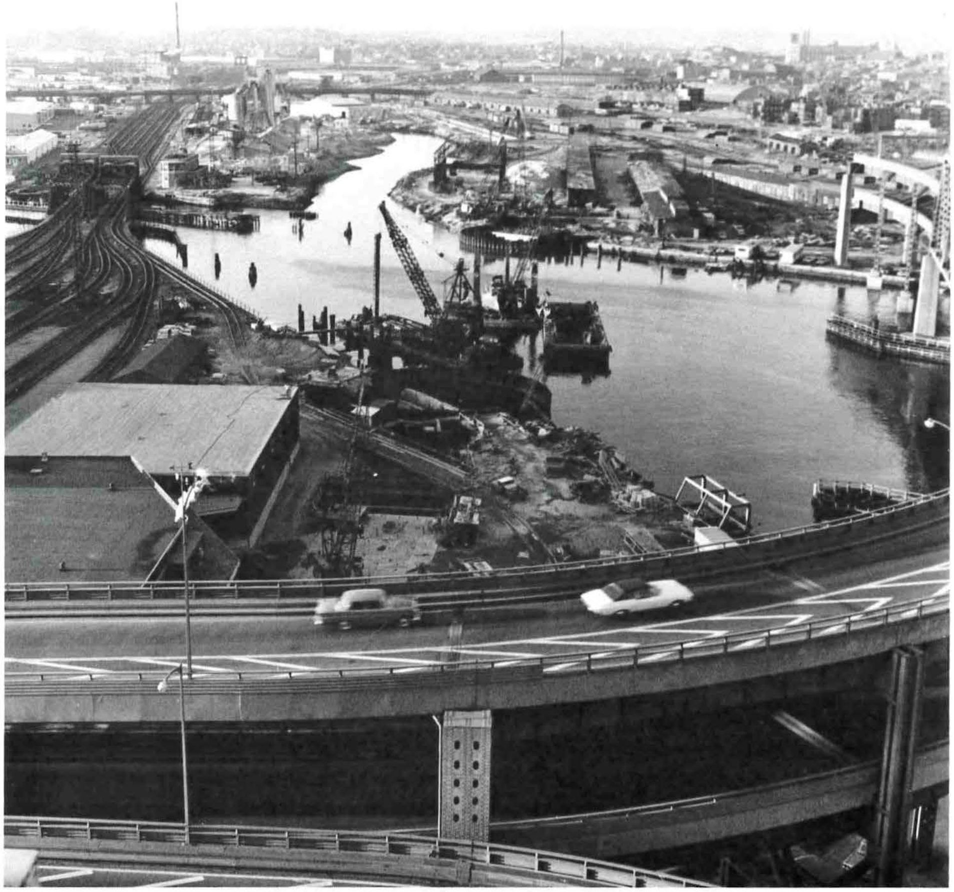
The successful bidder selected the option of using the prefabricated sunken tube method of construction.

To connect the prefabricated tunnel sections to the land tunnels, large transition sections had to be constructed on each side of the river. These transition sections were constructed inside two mammouth single-cell cofferdams, 96 feet in diameter, with no transverse bracing. These cofferdams were of the compression type with steel sheeting driven on the outside of 360 degree ring walers, fabricated of circular steel beams weighing 160 pounds to the foot. At the time, they were the largest cofferdams ever constructed of this type.

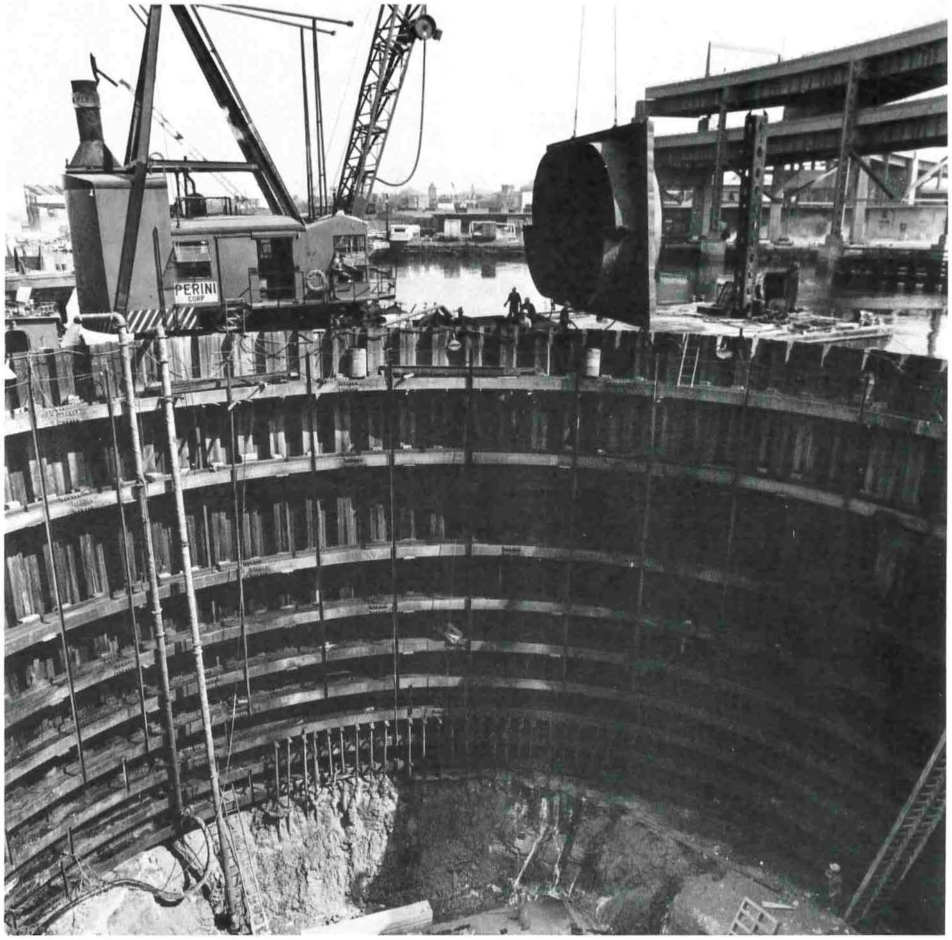
After the transition sections were constructed inside the cofferdams, the contractor positioned in place and sunk the prefabricated tubes.



Aerial view, taken from the roof of the Anelex Building at 150 Causeway Street, shows the construction of the ***cofferdams*** *for the installation of the prefabricated tunnel sections under the Charles River.*



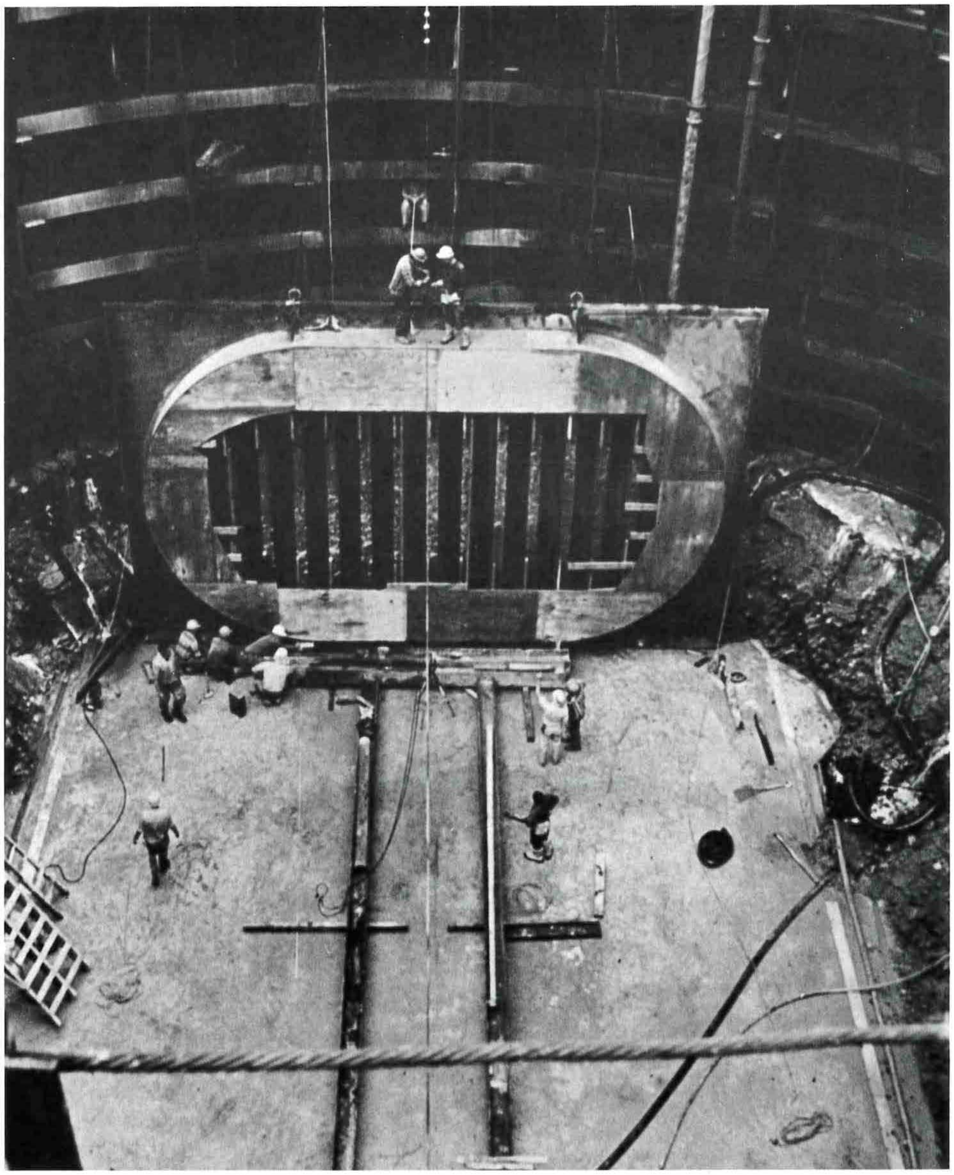
*Panoramic view of the Charles River area shows the **south cofferdam** at the head of Accolon Way in the center foreground. The **north cofferdam** and Miller's River is in the center background.*



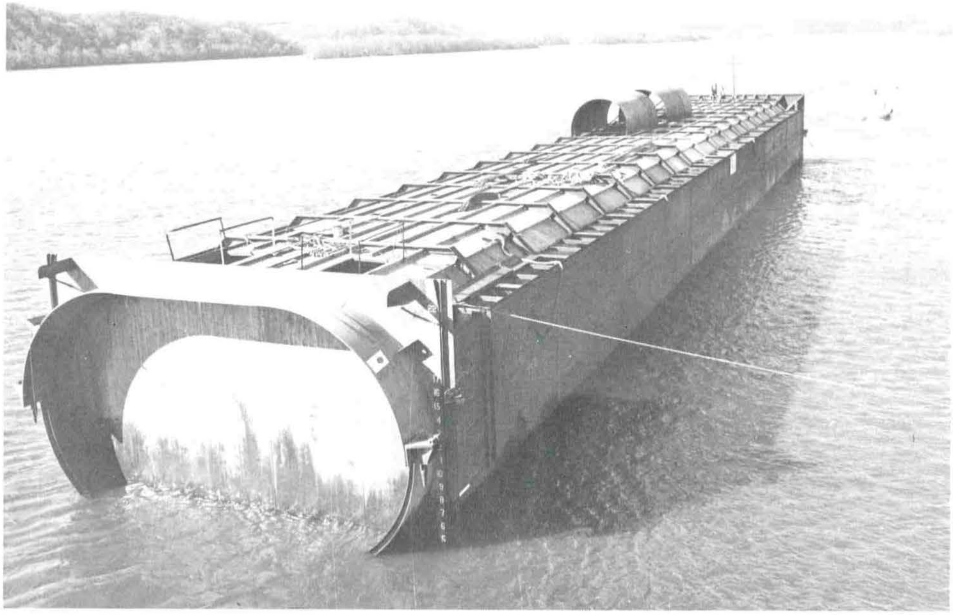
*Close-up view of the **unsupported south cofferdam**, which was constructed with no traverse bracing whatsoever.*

Noted facts relating to these tubes:

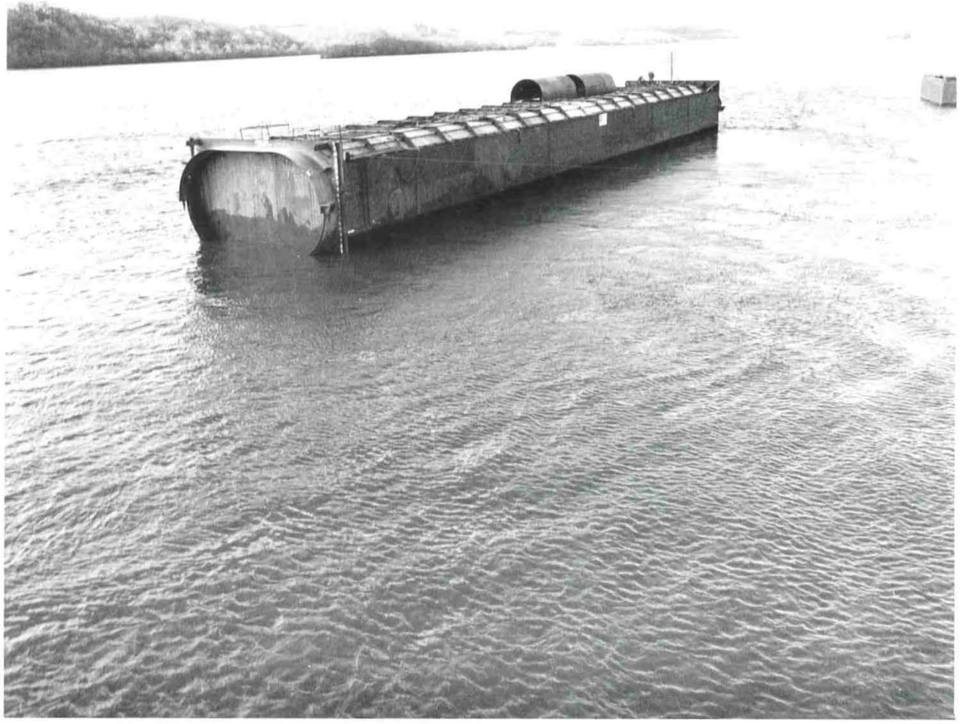
- Each of the two sections is 232 feet long; 37½ feet wide and 22½ feet high. Each weighs 5,700 tons.
- In place on the river bottom, the sections are 18 feet below the low-tide surface of the river waters.
- The river tunnel sections were designed by Praeger, Kavanagh and Waterbury, a New York engineering firm, working with Colonel S.H. Bingham Associates, Inc., consulting engineers for the Haymarket-North Extension.
- The steel shells of the tube sections were constructed on the shipways at Wiley Manufacturing Company, Port Deposit, Maryland, and then towed by seagoing tug to the contractor's Marine Division at East Boston, where each tube section was lined with reinforced concrete.
- The first tube section arrived in Boston on October 20, 1967; the second on December 6, 1967.
- The reinforced concrete walls, roof and floor of the tube sections are shaped like a subway tunnel and are 15 inches thick.
- Each tube has two trackways, which are separated by a concrete center wall with openings every 20 feet to permit access to either track.
- These sections were positioned in place and sunk in February and March of 1970.



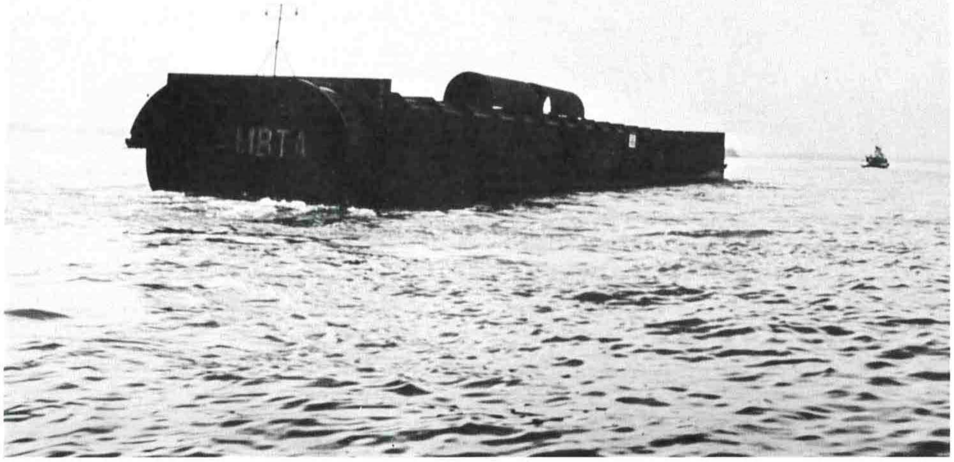
***Transition sections**, such as this one at the base of the north cofferdam, were constructed prior to the positioning and sinking of the prefabricated tunnel tubes.*



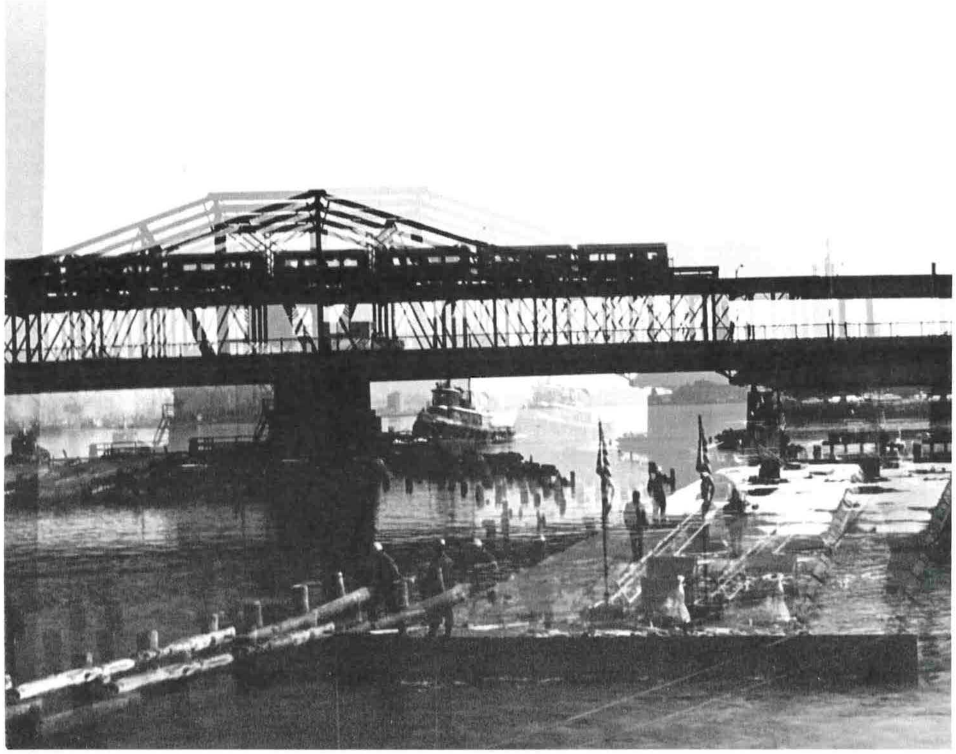
The ***North Tunnel Tube*** *is shown enroute from Maryland, where it was prefabricated and then towed to the contractor's marine division location in East Boston for concreting and outfitting.*

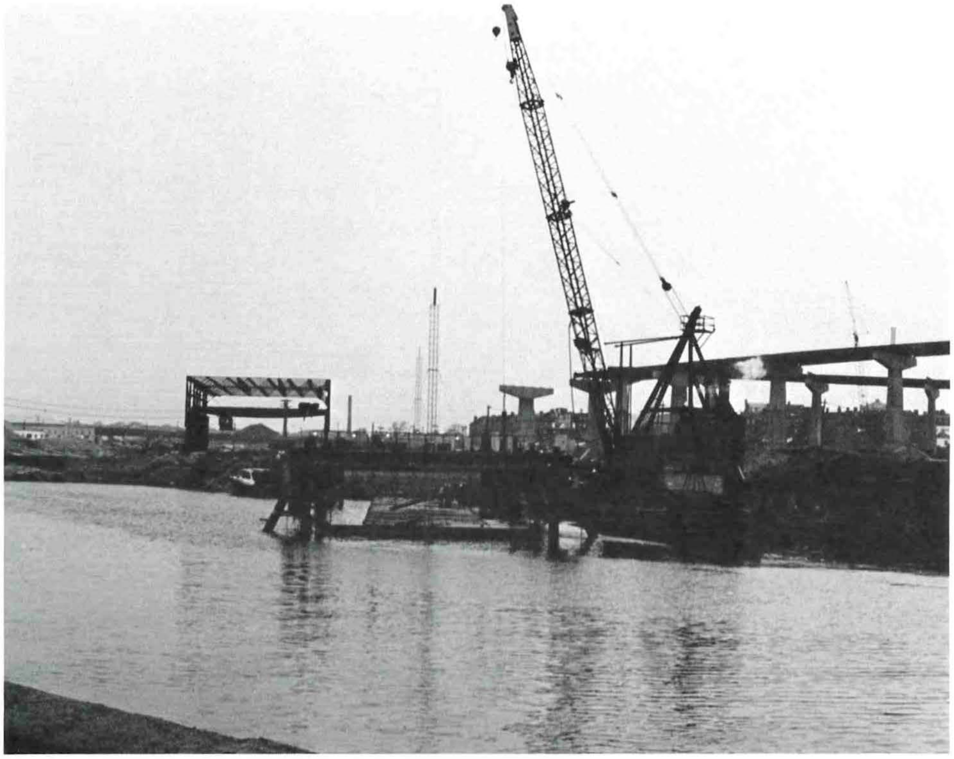


Another view of the ***tunnel tube****, taken outside of Port Deposit, Maryland, shortly after launching.*



***North Tunnel Tube** arrived in Boston Harbor on December 6, 1967.*





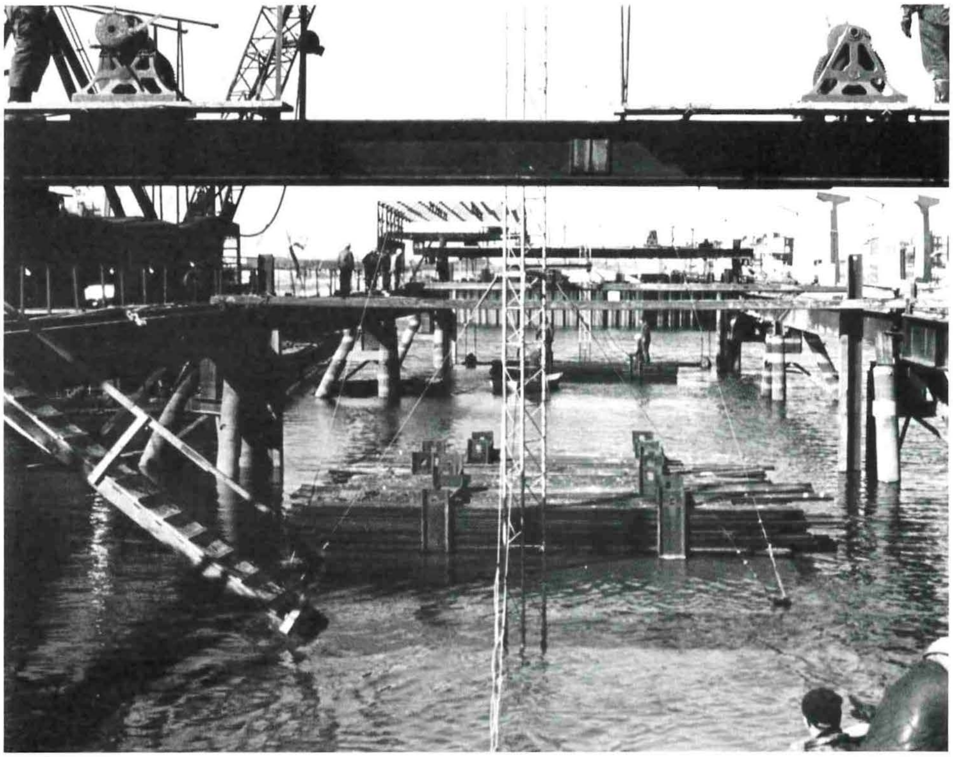
The subway section, north of the river and the ramp to the ground surface, were also different in design.

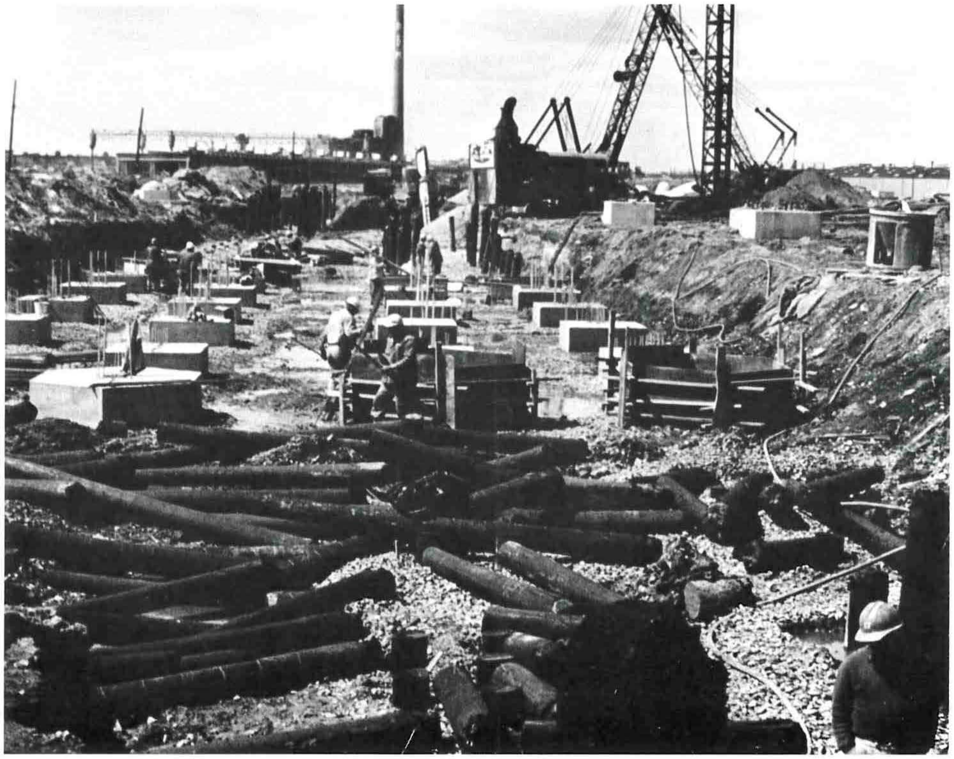
This area was complicated by its location on the old Fitchburg Railroad trestle, B & M yard tracks and freight houses. Tracks had to be relocated; freight houses underpinned or protected; and old timber piles, 35 to 45 feet long, 5 foot on centers had to be extracted from the ground.

Due to the numerous existing piles in the ground, a section of the sheetpile retaining walls encroached into the design area of the tunnel, which necessitated the redesign of approximately 300 feet of cast-in-place concrete tunnel to a structural steel and concrete tunnel.

In addition to the 16 months delay resulting from approvals for the underpinning of the Central Artery, there were eight labor strikes during the construction of this contract, amounting to a total of 273 calendar days lost.

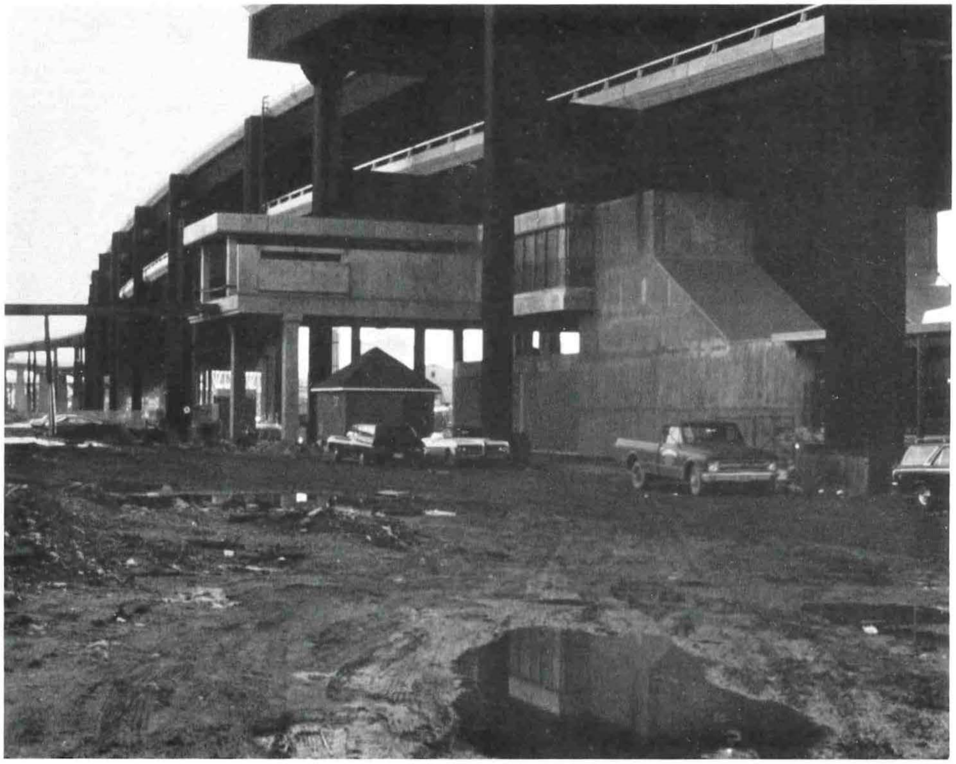
A variety of equipment and carefully coordinated operations were required for the ***positioning and sinking*** *of the tunnel tubes to their designated locations under the Charles River. Shown are some of the steps included in these operations, accomplished in February and March of 1970.*



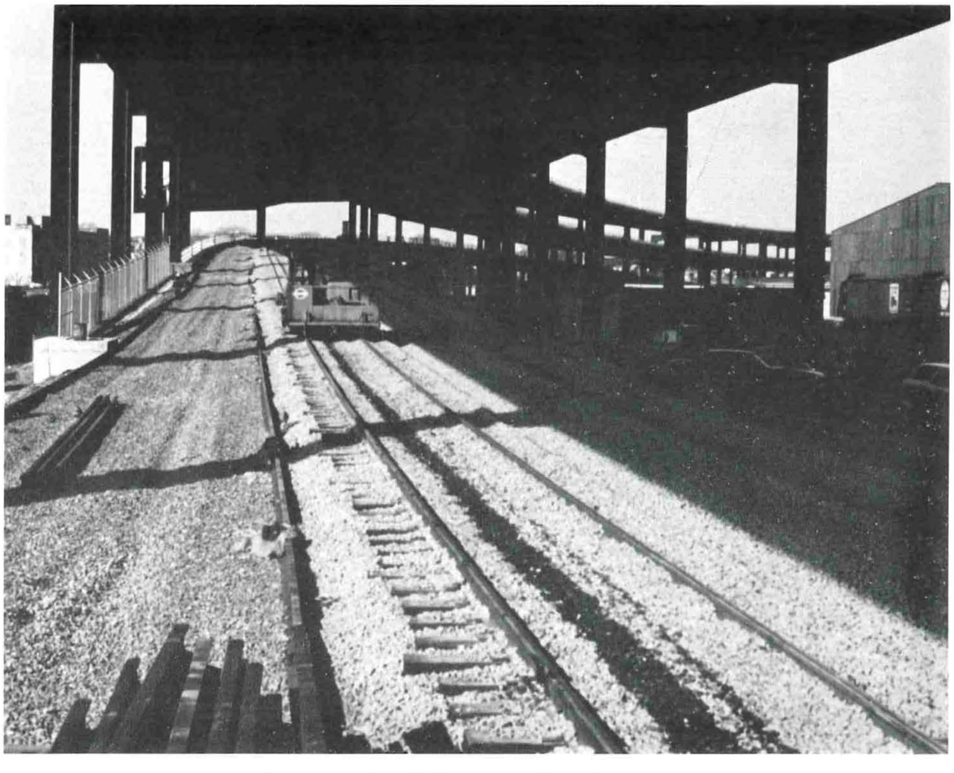


View of early construction activity for ***Community College Station****, showing support piles and concrete foundations for the station platforms.*

Platform *for Community College Station shown under construction beneath the structure for Interstate Highway 93.*



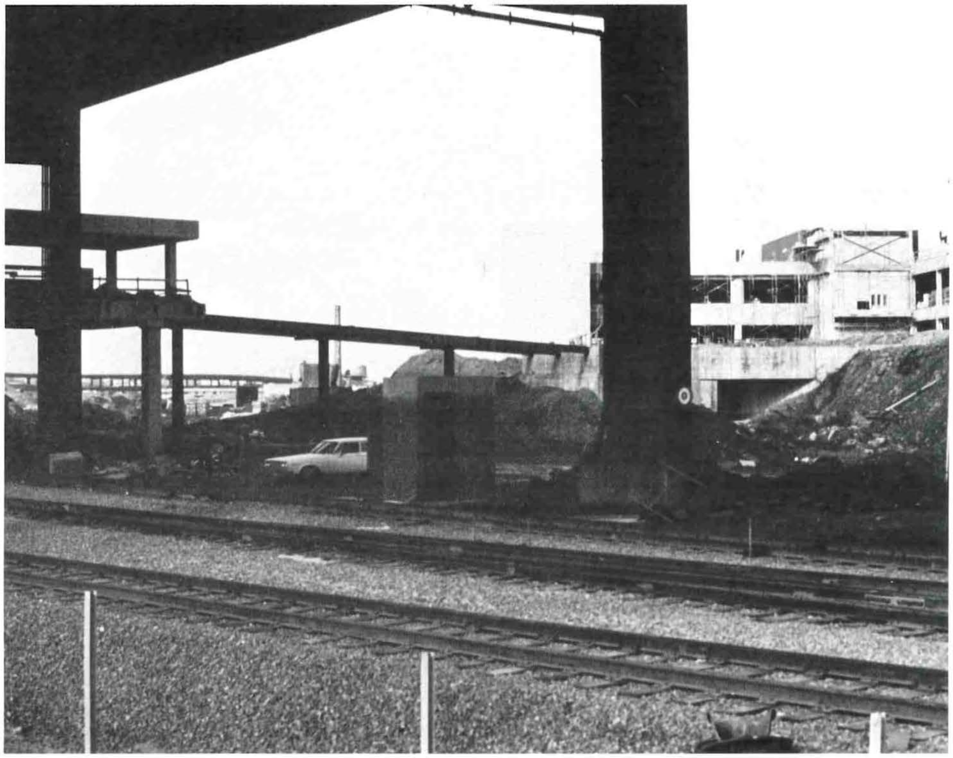
Later view of the ***upper level*** *of Community College Station, showing preliminary construction of the pedestrian walkway to Bunker Hill Community College.*



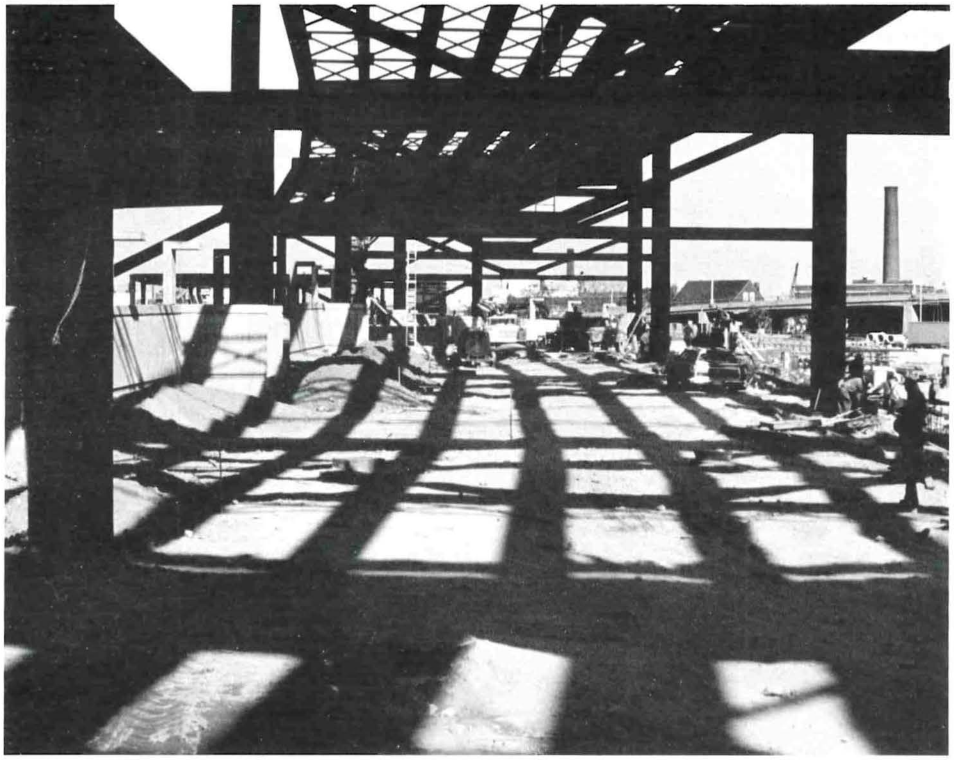
The ***Tracks*** *between Community College and Sullivan Square were constructed under the structure for I-93, for the most part, at ground level, with the exception of a 1,500 foot long stretch that was constructed on a viaduct over the B & M's Mystic Division tracks.*

Construction of the Second Section

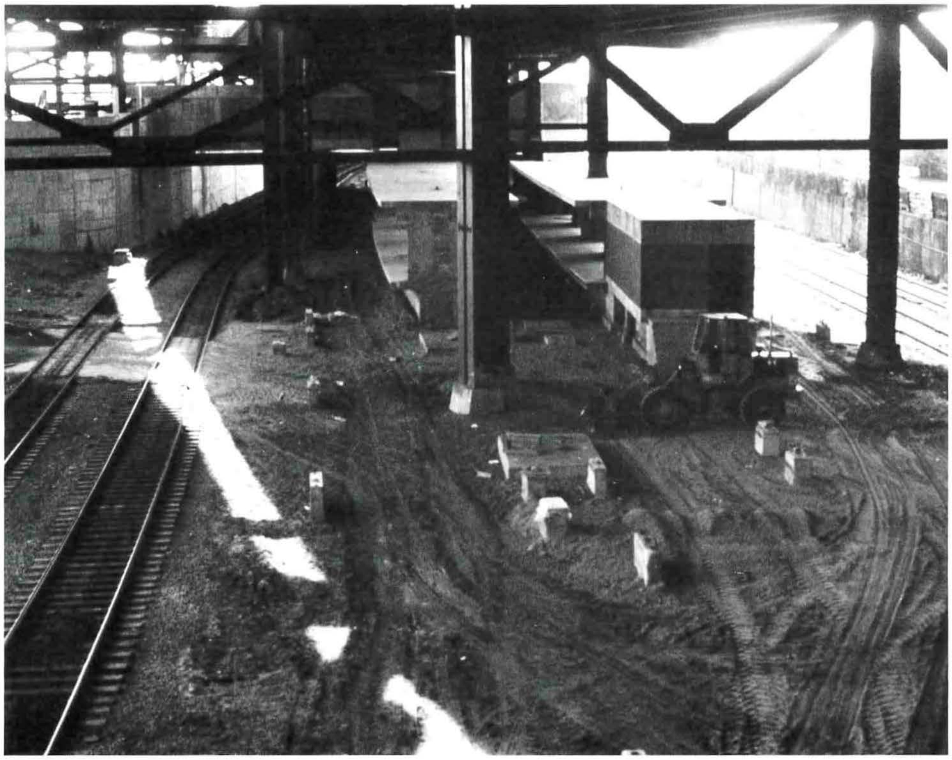
The construction of the second section commenced on June 16, 1969 and was completed on July 18, 1973. Within this area, the system branches into three tracks, and requires the reconstruction of the Prison Point Bridge and Cambridge Street Bridge. It also included the construction of the Community College and Sullivan Square Stations, which were by no means similar. Although both are two-platform, two-level surface stations constructed of cast-in-place concrete, Community College included the construction of a pedestrian overpass and walkway to the college, while Sullivan Square included a two-level busway, kiss-and-ride driveway and parking lot for 180 cars. Both stations, however, were constructed beneath the overhead elevated structure of I-93, also under construction at that time. At Sullivan Square Station, columns to support I-93 were installed through the platforms of the station.



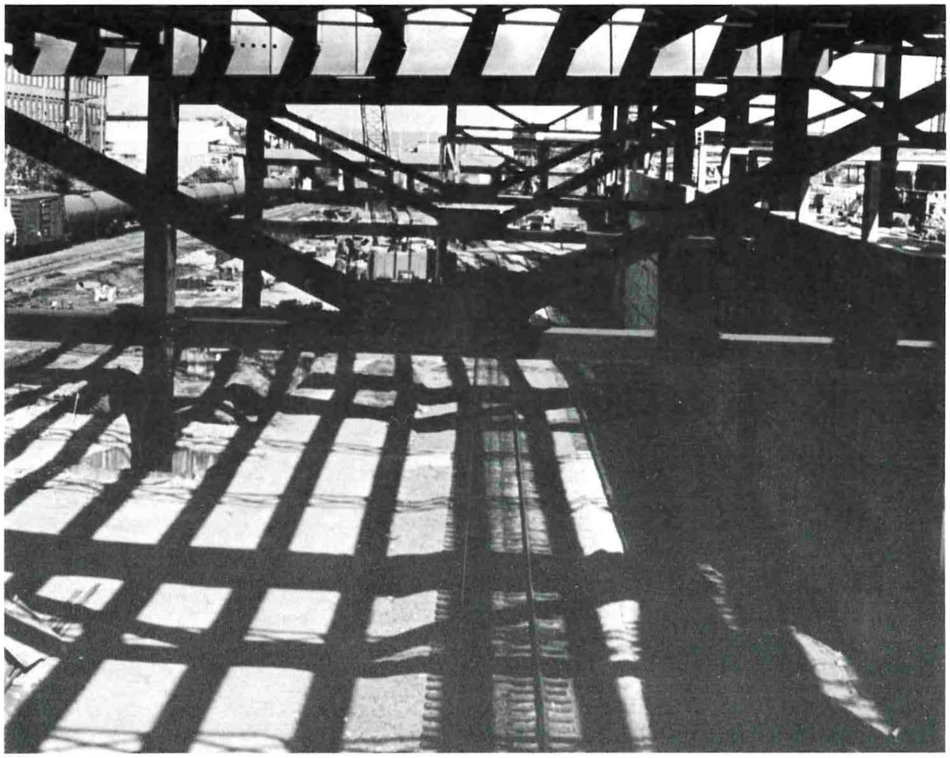
Area view *of tracks and structure for Community College Station and pedestrian walkway to Bunker Hill Community College with I-93 towering above.*



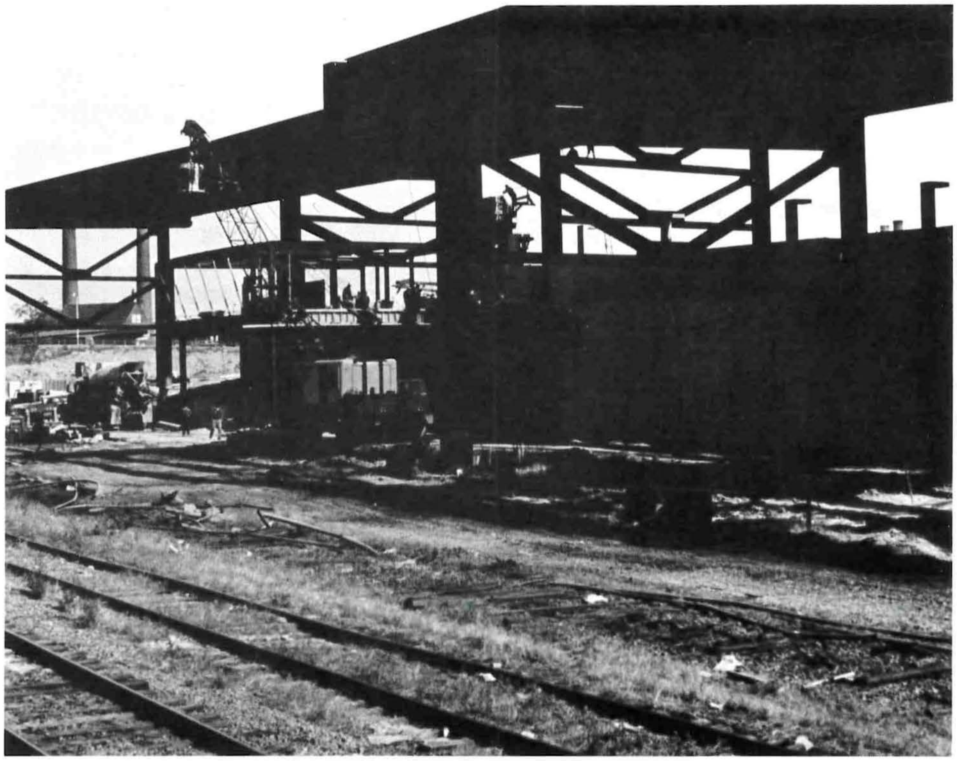
Sullivan Square Station *was constructed below the elevated highway structure for I-93, which also was under construction by the Mass. DPW at the time of station construction.*



Elevated structure for I-93 overshadowed the site for ***Sullivan Square Station.***



View of construction of the ***canopy and platform for Sullivan Square Station****,*
beneath the structure for the Interstate Highway 93.



Another view of ***Sullivan Square Station*** *construction, showing steel structure and cast-in-place concrete walls for the station's upper level.*

View of the Sullivan Square Station area *during early station construction.*

Another view of ***trackway*** *under I-93 structure.*

Also included in this contract was the construction of a three-track viaduct over the Boston & Maine Railroad tracks.

The construction of these structures contributed to the complexity of the contract as it was necessary to coordinate all design and construction with the Mass. DPW, in conjunction with their construction of the overhead Interstate Highways I-93 and I-95, with the B & M and Penn Central Railroads, the Metropolitan District Commission (MDC), and the City of Boston Redevelopment Authority (BRA).

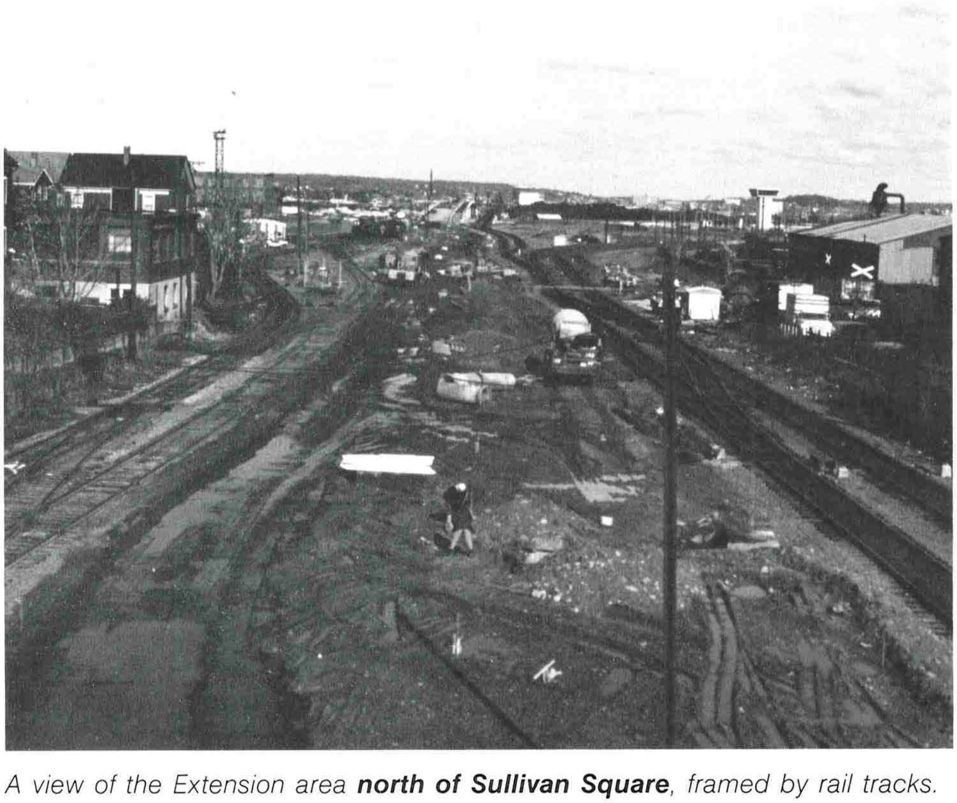
Overview *of railroad track network, looking toward Boston with Hood Milk facility at left. Construction of the Haymarket-North Extension was complicated by the requirement that construction not interfere with railroad service.*

In this 6,000 foot, $11 million section, there were three Mass. DPW contracts totaling approximately $45 million, two B & M Force Account Contracts totaling approximately $4.2 million (one was a three-party contract which involved the DPW, the MBTA and the B & M on a 51% and 49% cost share between the DPW and MBTA), and one MDC-DPW joint venture to design and construct the new $4 million Prison Point Bridge and new 16″ water main for the City of Boston. A cost-sharing agreement between the Boston Redevelopment Authority and the MBTA also was negotiated to share costs for the track, power and signal work.

In addition to problems resulting from all agencies having to coordinate and review design through this area, the task was further complicated by the requirement that construction be performed concurrently with the MDPW construction of the overhead I-95 and I-93 highways through live commuter rail passenger and railroad freight operations.

*Active **rail lines**, as those shown here north of Sullivan Square, were a major consideration in construction of the Haymarket-North Extension throughout its alignment, including this area.*

Another problem occurring in the early stages of construction was failure of the Railroad to maintain its Force Account work schedule with the contractors' schedules, which was noted by the MDPW, the MBTA and the B & M Railroad itself. However, through the efforts of all concerned parties, the contractor maintained his schedule through 50% of the job, until the construction of the Mystic Branch Viaduct and new Sullivan Square Station commenced.



*A view of the Extension area **north of Sullivan Square**, framed by rail tracks.*

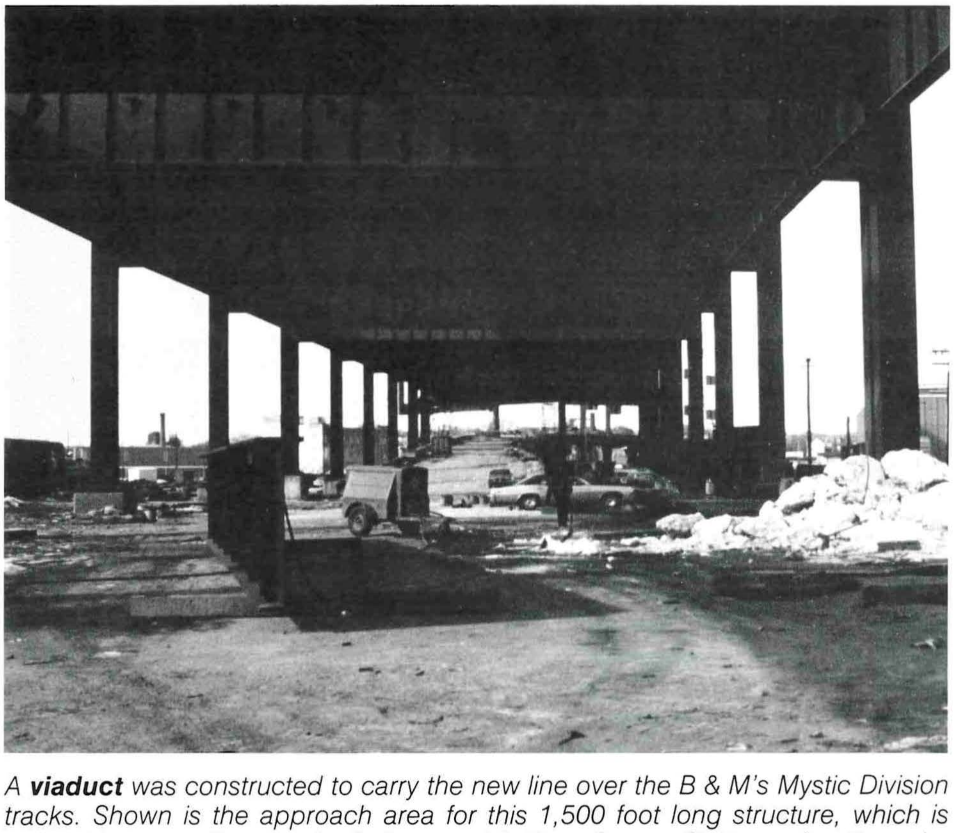
The Mystic Branch Viaduct

*Site view, showing construction of the **viaduct structure**, which consists of 20 bridge-type spans with ramp approaches at the north and south ends.*

The viaduct structure is located between the Community College and Sullivan Square Stations and carries the three rapid transit tracks of the Extension over the tracks of the B & M Railroad Mystic Division tracks.

The structure consists of 20 bridge-type spans with incline approaches at the north and south ends. At each end, there is an incline grade of 3.9% to the center, where the structure has a minimum clearance of 22′-6″ over the B & M tracks.

The spans vary in length from 48 feet to 91 feet. The approach incline structures are approximately 200 feet long on the south end and 275 feet long on the north end. Twelve (12) of the spans are supported on solid concrete piers and eight (8) are supported on steel column bents. All of the piers, column bents, approach structures and abutments are founded on concrete footings supported by concrete-filled steel pipe piles.



*A **viaduct** was constructed to carry the new line over the B & M's Mystic Division tracks. Shown is the approach area for this 1,500 foot long structure, which is located between Community College and Sullivan Square Stations, directly under the I-93 elevated structure.*

The superstructure is comprised of typical deck-type steel girders carrying a reinforced concrete deck slab, which supports the track bed, consisting of stone ballast, wood ties, steel rails and pertinent facilities related to power cables, duct lines, signals, etc.

For nearly its full length, the viaduct is located directly beneath the elevated highway structure (I-93), and many of the highway structure footings are common with the viaduct footings.

During the construction of the viaduct, delays attributed to the Railroad amounted to ten months. Additional delays attributed to labor strikes resulted in 81 days lost. These delays were not concurrent or overlapping.

North of Sullivan Square, design and construction was delayed in 1970 and 1971 by arbitration hearings relating to the acquisition of the B & M Reading Branch by the MBTA. The Reading Branch was finally acquired in the fall of 1973. Until this time, the Railroad was reluctant to review design plans and was uncooperative in negotiation and execution of Force Account agreements and construction permits.

Another view of ***viaduct construction****, which required extensive coordination with numerous state and city agencies and the railroads due to rail activity and the construction of Interstate Highways I-93 and I-95 in the same area.*

Construction of the Edward Dana Bridge

The construction of the Edward Dana Bridge over the Mystic River in Somerville and Medford commenced on September 24, 1969 and was completed on July 14, 1972. The bridge was dedicated in honor of Edward Dana, General Manager of the former Boston Elevated Railway and Metropolitan Transit Authority, on June 15, 1973.

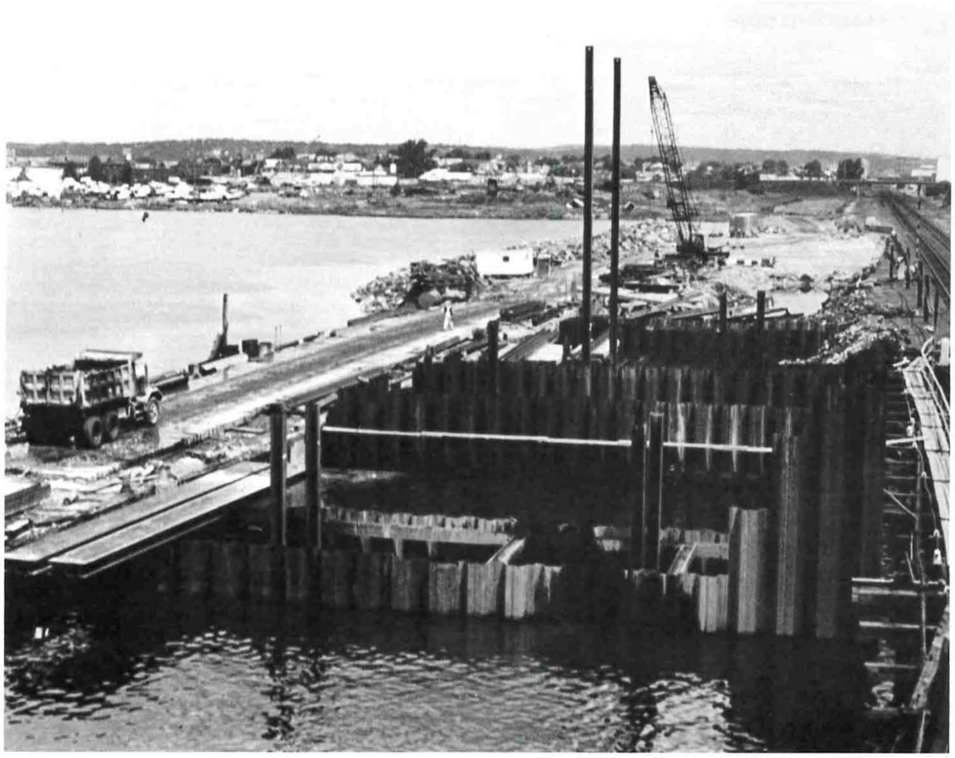
Because the bridge crosses over the Mystic River and abuts MDC property with its approaches on Boston & Maine Railroad land, its design and construction required coordination with the MDC, U.S. Coast Guard, Army Corp of Engineers, and Boston & Maine Railroad.

The Dana Bridge consists of two separate structures, one for rapid transit and one for railroad. The rapid transit bridge is an 11-span, deck-type, steel plate girder structure of high strength weathering steel, 965 feet in length and constructed on concrete piers and abutments. Total length including the approach ramp and structures is 2,125 feet. The bridge is 45 feet wide and carries three (3) rapid transit tracks providing inbound, outbound and express services. The abutments, retaining walls and bridge piers were supported on concrete footings and concrete-filled pipe piles driven to refusal.

A companion structure of steel box-girder construction of high strength weathering steel, approximately 19 feet wide, was built adjacent to the bridge, on its easterly side. This structure, which opened for revenue service on December 3, 1972, carries a single track to accommodate Boston & Maine Railroad freight and commuter rail service, as the old draw bridge over the Mystic River had to be demolished to accommodate the new bridge.

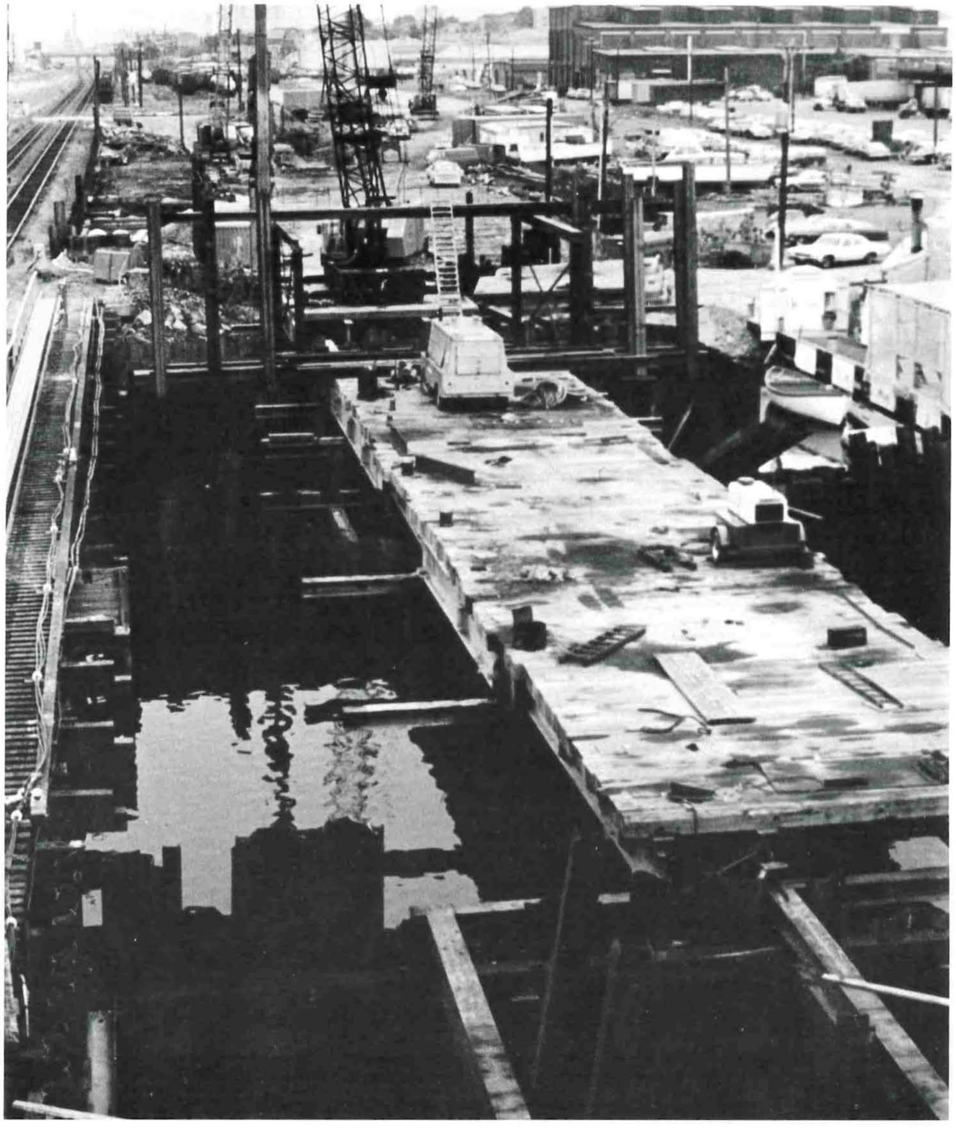
The construction of the Edward Dana Bridge also encountered delays due to labor strikes and financial and legal issues involving the Boston & Maine Railroad. Although the contractor began construction on September 24, 1969, work was restricted to the north approaches and cofferdam construction from midstream north until January of 1970. This was caused by the reluctance of the Boston & Maine, which at that time was negotiating the sale of the Reading Branch line with the MBTA, to enter into a Force Account agreement for the relocation or removal of the railroad side tracks on the south side of the bridge.

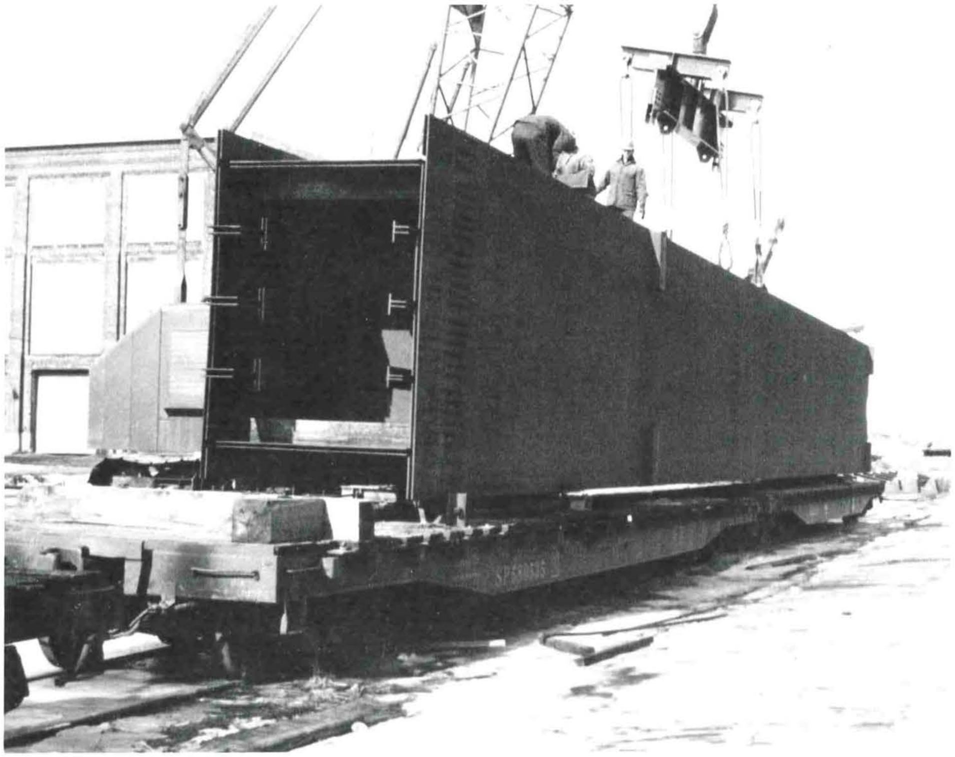
Total days lost due to difficulties was 93 calendar days.



Edward Dana Bridge, *which carries the Extension over the Mystic River, is an 11-span, deck-type, steel plate girder structure with approach ramps, totaling 2,125 feet in length. Activity related to the installation of the steel sheeting for the girders is shown here.*

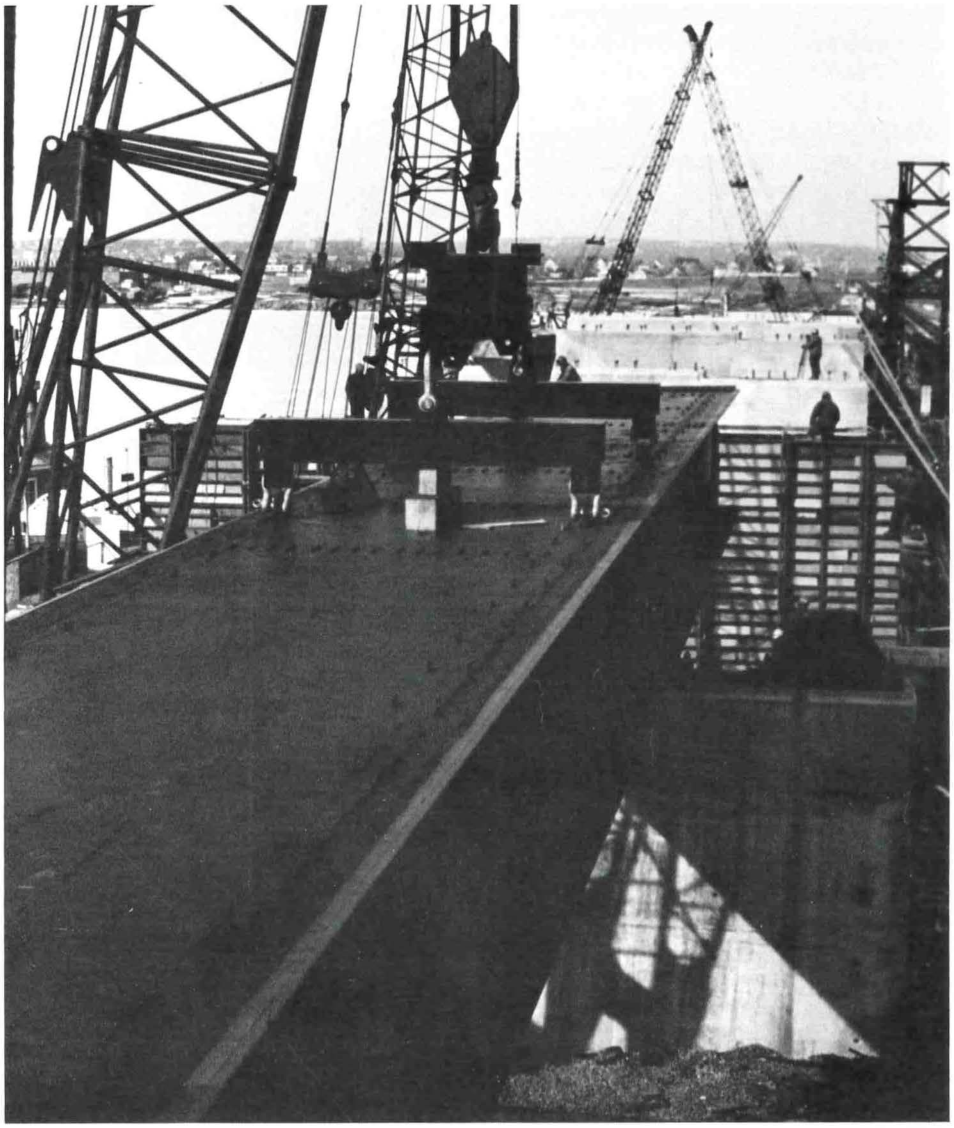
Another view of **installation of the bridge's foundation**, *with B & M freight and commuter rail tracks at left. A companion structure was later built adjacent to the bridge that included a single track to accommodate both freight and commuter rail service.*

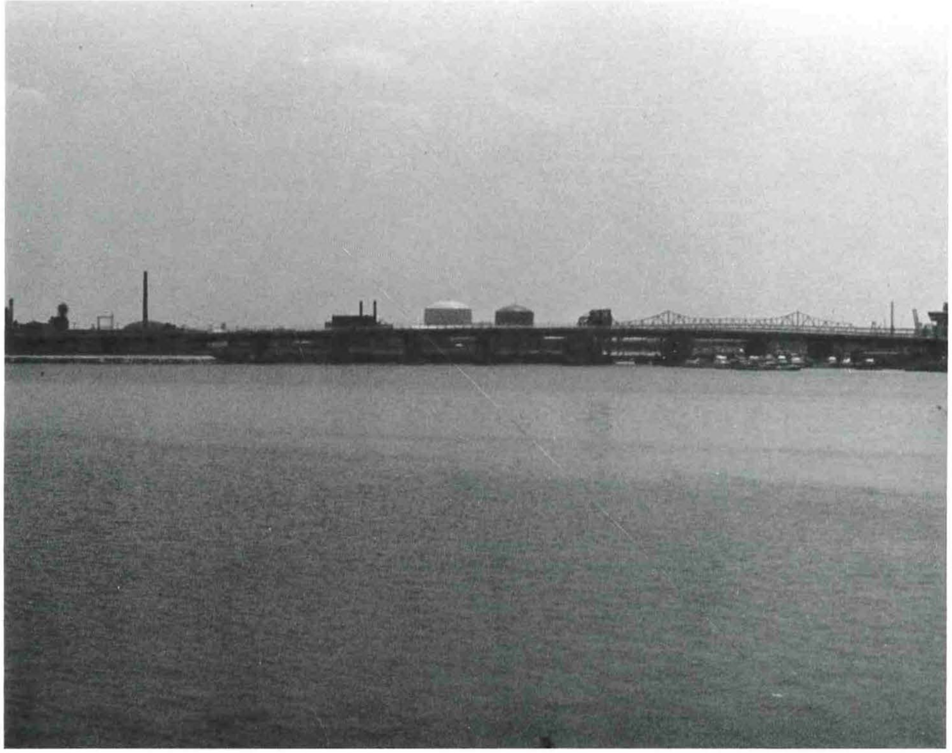




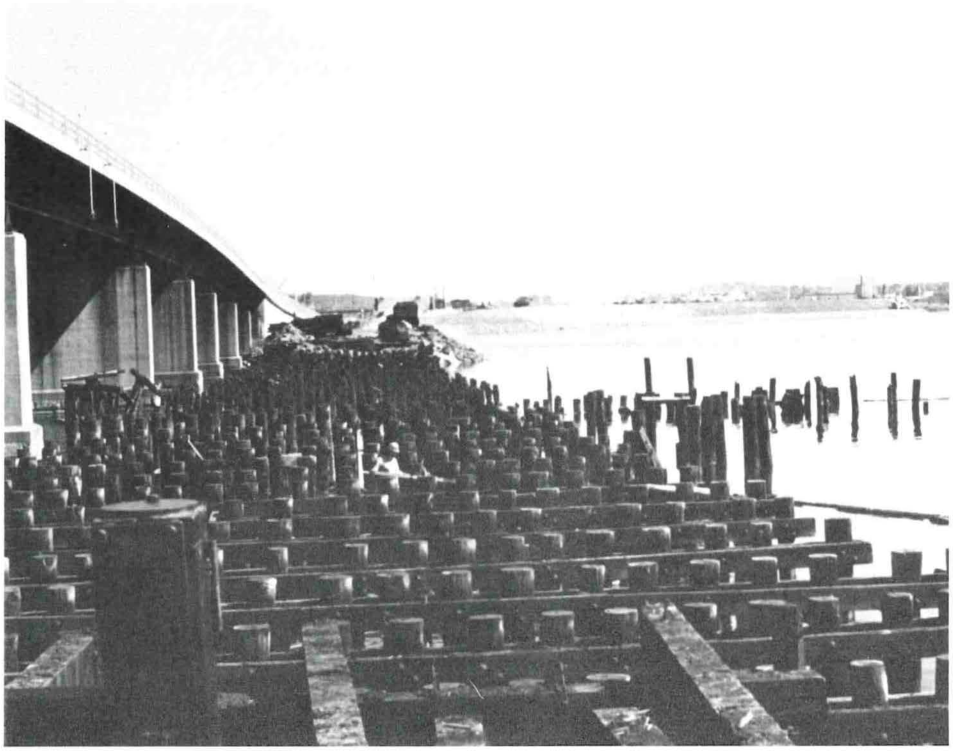
The massive ***steel-plate girders*** *for bridge construction were delivered to the site by use of the adjacent rail line.*

The ***girder sections*** *were then placed, as shown, to construct the spans.*

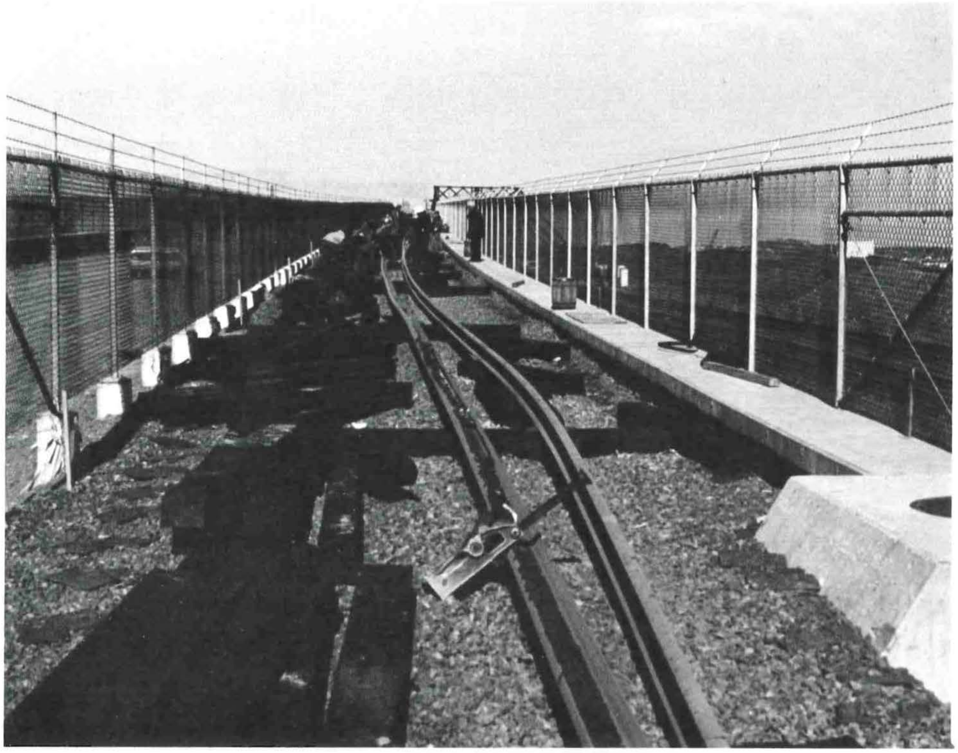




A view, looking east, of the ***Dana Bridge****, which was dedicated in honor of Edward Dana on June 15, 1973.*



The structure of the adjacent ***Draw #8*** *railroad bridge was* ***demolished*** *following the construction of the new bridge.*



View of the companion railroad structure, showing ***placement of continuous welded rail and ties*** *for the single rail track designed to carry both B & M commuter and freight service over the Mystic River.*

Construction of the Medford Underpass

The contract which included the construction of the Medford Underpass and a section of roadbed and drainage between Sullivan Square and the Edward Dana Bridge commenced on February 22, 1971 and was completed on July 2, 1974.

The Medford Underpass, which carries the Extension under the tracks for the former Boston & Maine Medford Branch, adjacent to Corporation Way in Medford, is approximately 1,350 feet in length. It consists of walled, open-cut ramp sections at each end, approximately 500 feet long, and a roofed center section, approximately 350 feet long between portals.

The invert, walls and roof of the Underpass were constructed of reinforced, cast-in-place concrete. The north ramp, for a distance of 200 feet at the northerly end, was constructed on concrete-filled steel piles.

This Underpass was originally designed as a viaduct, but the City of Medford raised objections to the design of an overhead structure and requested the rapid transit tracks be depressed under the railroad tracks. The MBTA was acquiescent to this request.

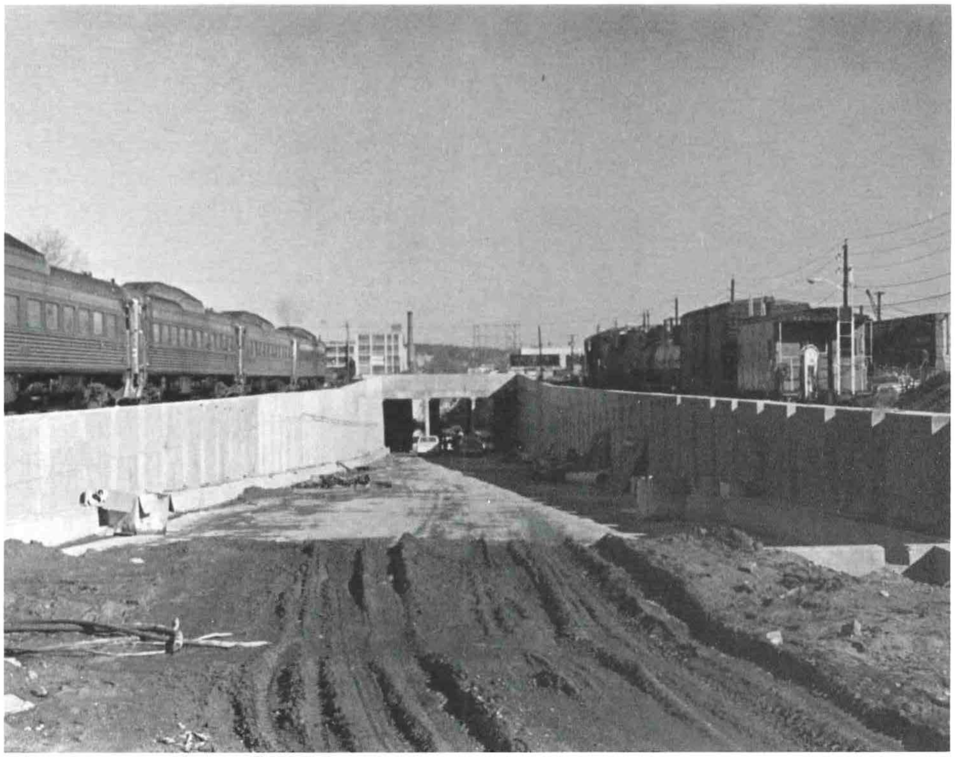
In order to construct the tunnel, the utility companies were required to relocate telephone, electric and gas lines from the westerly side of Corporation Way to the easterly side. This activity, however, was delayed due to difficulties in obtaining the required construction permits, which were not obtained until late spring and early summer of 1971.

After the utility companies relocated their respective lines, the Boston & Maine was required to construct two new tracks for the continuation of passenger and freight service through the construction area. By this time, however, the Boston & Maine was bankrupt, and suppliers were reluctant to deal with the Railroad company. Only through efforts by the MBTA did suppliers, including the critical steel supplier, consent to make deliveries.

Another major problem encountered in this area was the discovery that an existing MDC water line was not accurately depicted on the design and construction plans. This was not detected until the contractor exposed the line and the MDC completed an inspection. A number of design changes were required to accommodate the line and continue construction.

The delays incurred by the utility companies' delays in obtaining construction permits, the problems relating to the Boston & Maine's financial situation, the MDC water line and labor strikes caused the contract to be delayed by 15 months. However, the time lost here did not impact the overall construction of the new line from Revere Beach Parkway through Malden Center, which was completed in 1975.

*The **Medford Underpass** carries the Extension under the B & M's Medford Branch tracks in Medford, beyond the Wellington Complex. Preliminary construction for the structure, which is approximately 1,350 feet long and consisting of walled, open-cut ramp sections at each end and a roof center section between portals, is pictured here.*



*Rail activity continued during construction of the **Medford Underpass**, which was constructed of cast-in-place concrete. Shown is the 200-foot-long north ramp and its foundation on cast-in-place concrete piles.*

View of excavation and material for the construction of the ***Medford Underpass*** *in West Cooperation Way, south of the Revere Beach Parkway.*

Construction of the Wellington Complex

The construction of the Wellington Complex was divided into two separate contracts: Wellington Station, and the Wellington Yard and Shops. Both contracts commenced in 1973, and the new facilities opened in 1975.

Wellington Station is located on the northerly side of the Mystic River in Medford, east of Wellington Circle and to the south of the Revere Beach Parkway.

Entrance to the station is provided at the upper level of the control house, which is located at the northerly end of the station and includes the area where the fare collection facilities are situated.

From the control house, escalators and stairways connect to the two platforms below, providing access to all three of the Extension's tracks. A busway area, as well as parking facilities for approximately 1,000 vehicles, is located on the east side of the station, adjacent to the Revere Beach Parkway.

From the busway and parking areas, access to the control house is provided by a pedestrian passageway structure located above track level. The passageway is fully enclosed, with a concrete roof, and sidewalls consisting of tinted safety-glass panels.

The station building is basically of concrete construction, with interior finish features similar to those found in the other Haymarket-North Stations. These include paver-brick floors and glazed-brick wall panels.

The Wellington Maintenance and Repair Shops and Train Storage Yard are located between Wellington Station and Wellington Circle on the west, the Mystic River on the south and the Revere Beach Parkway on the north.

The maintenance and repair shop building is 460 feet long, 242 feet wide and 33 feet in height. It is constructed of heavy structure steel framing, including steel roof trusses. The exterior walls consist of pre-cast concrete panels; and the roof structure is constructed of cast-in-place, lightweight concrete slabs. The building is founded on concrete-filled steel pipe piles, which carry the reinforced concrete caps and beams supporting the floor system and walls.

The shop interior consists of a nine (9) track layout that enables trains to be positioned for cleaning, washing, inspection, and light and heavy repairs.

The shop track construction includes pits for inspection and repair work, overhead power lines, wheel truing machines, traveling cranes with lifting facilities, and pertinent equipment, including car-washing equipment and hydraulic jacks to lift a complete car.

Other buildings in the yard area include a signal tower, D.C. traction sub-station, and two D.C. circuit breaker houses.

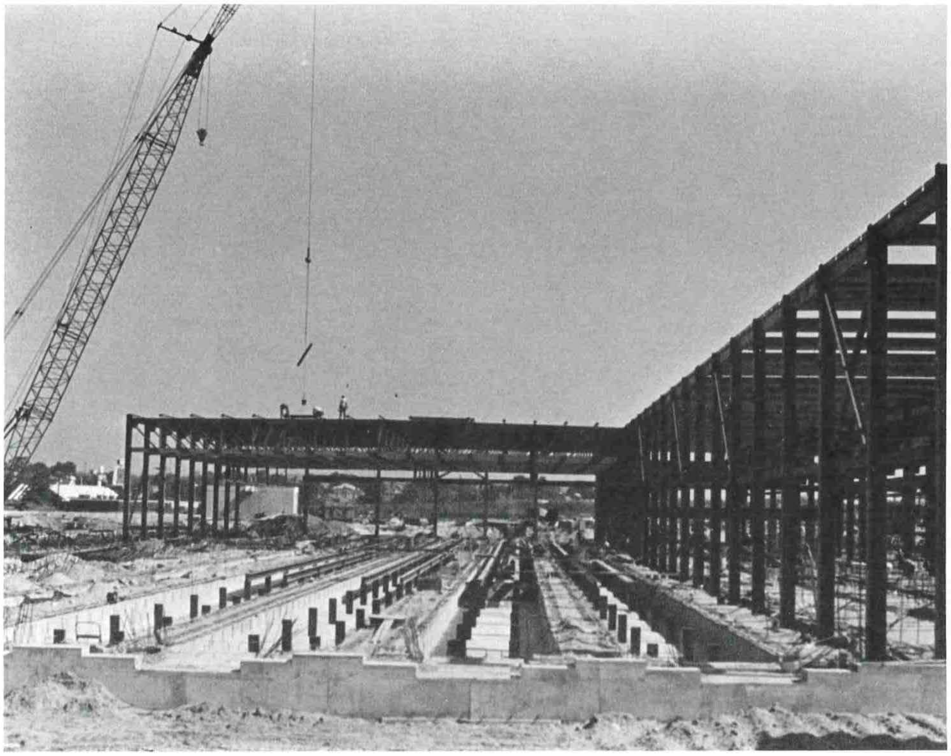
The train storage yard is adjacent to the west side of the maintenance and repair shops. It consists of 14 tracks, approximately 700 feet in length, that are accessible from both ends of the yard and the shop by means of a ladder track on the south end, and loop tracks on the north.

The construction of the Wellington Complex was affected by several problems that resulted in schedule delays. This included a one-year delay due to reluctance by the Boston & Maine Railroad to enter into a Force Account Agreement with the contractor.

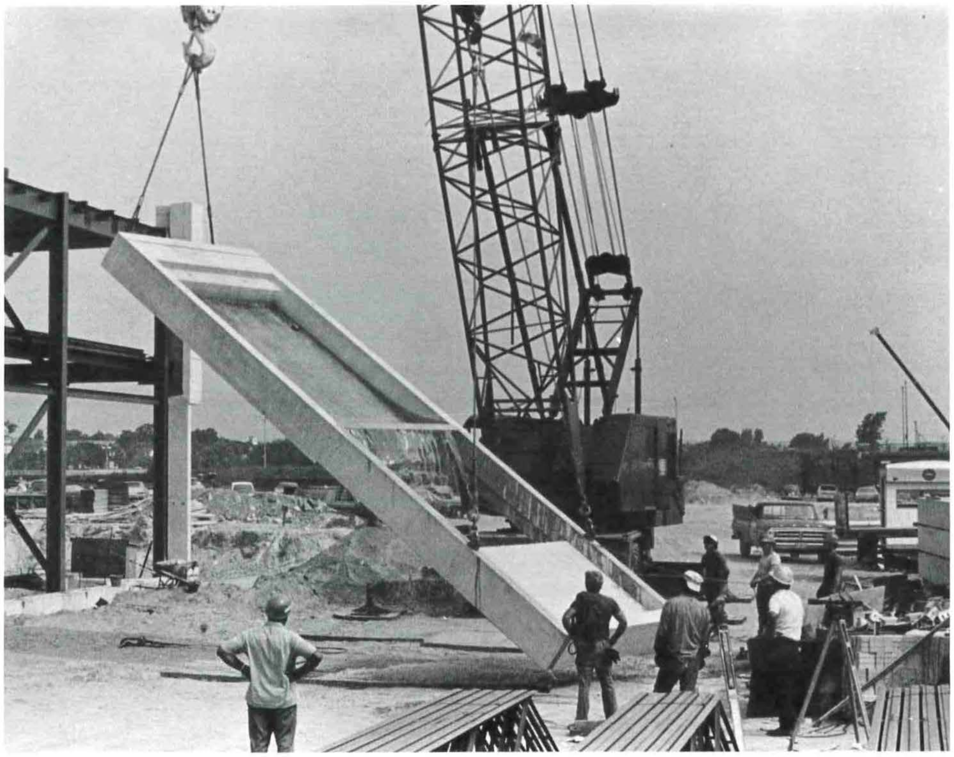
The contractor also experienced delays—and submitted a claim—as a result of problems encountered during the erection of the maintenance and repair building. Additional problems, including labor strikes, during the construction of the Wellington Complex, and delays in the delivery of supplies and equipment as a result of the 1973 energy crisis during the installation of track in the Wellington Yard, extended the contract time.

Labor strikes alone resulted in a loss of more than 170 days of construction time.

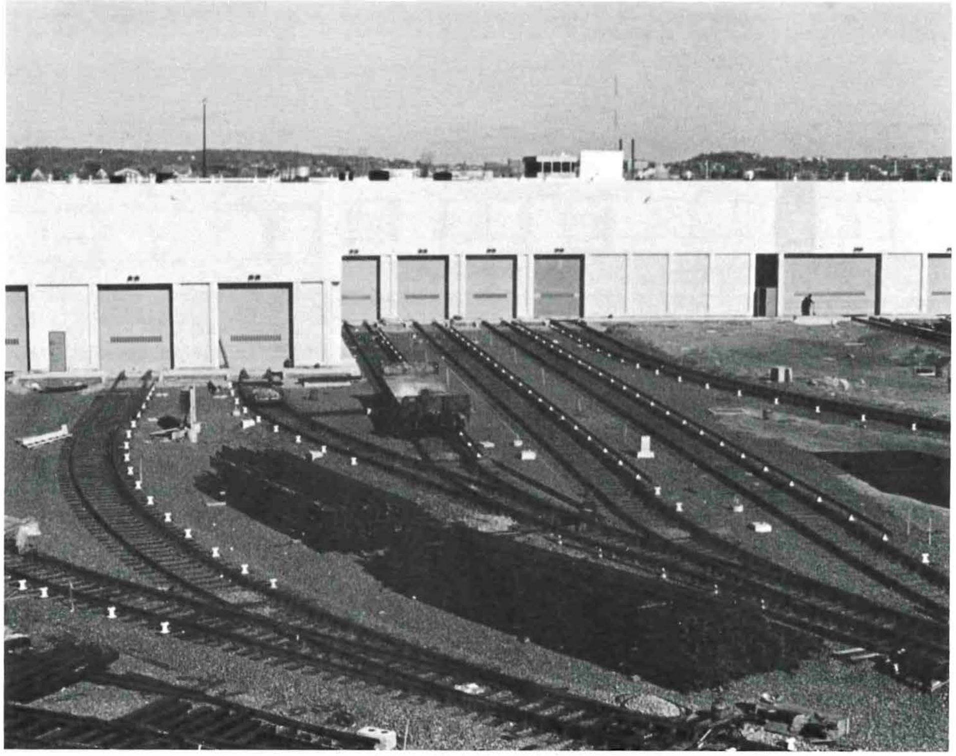
B & M Tracks are the focus of activity in this view of preliminary construction of the ***Wellington Complex****, located on an 18-acre site on the easterly side of Wellington Circle, south of the Revere Beach Parkway.*



The massive ***Maintenance and Repair Facility*** *is shown taking shape. Approximately 460 feet long, 242 feet wide and 33 feet high, the building was constructed of heavy structural steel framing, including steel roof trusses, and was founded on concrete-filled steel pipe piles which carry the reinforced concrete caps and beams supporting the floor system and walls.*



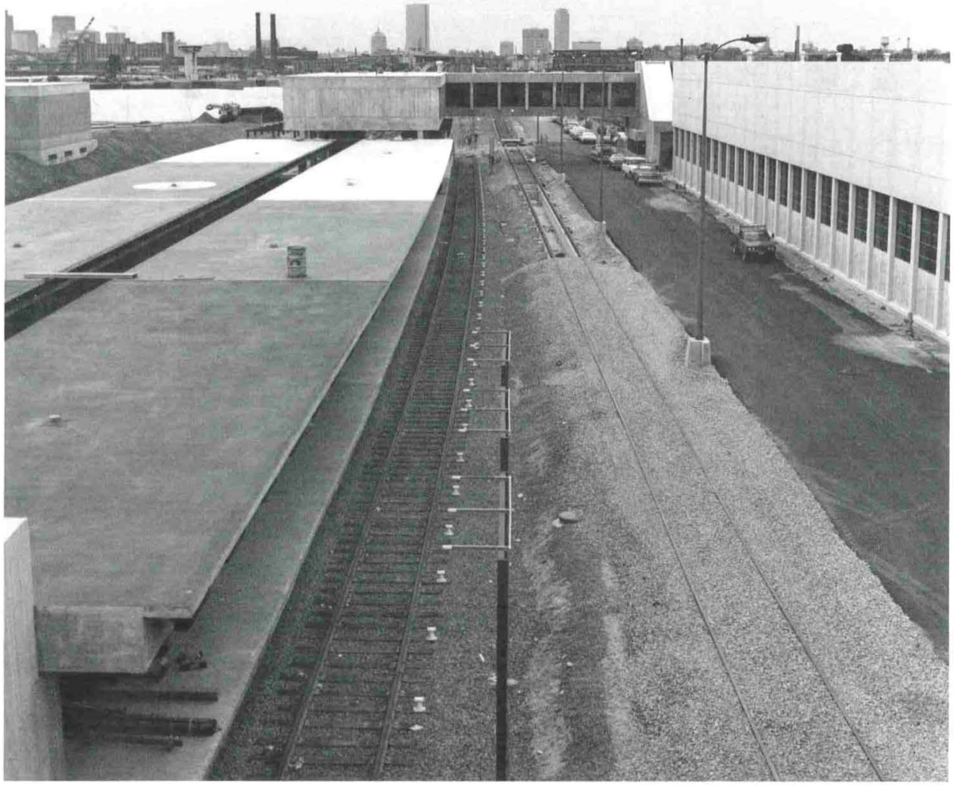
A **pre-cast concrete panel** is shown being hoisted for the construction of the building's exterior walls.



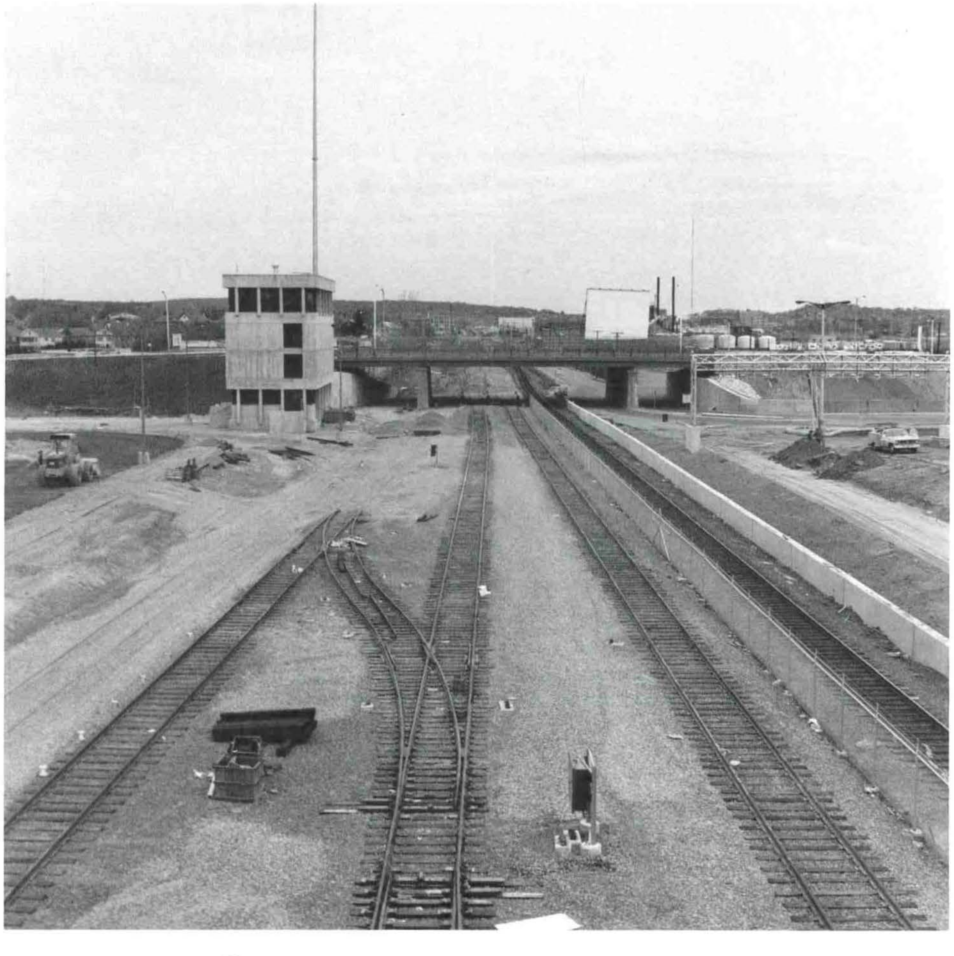
View of the nearly completed ***Maintenance and Repair Facility*** *showing the 9-track layout and entrances to the shop, which includes facilities for the cleaning, washing, inspection and repair of trains.*

Access Road *to the maintenance shops parking lot at the Wellington Complex.*

Wellington Station *is a two-level facility with two station platforms that serve three rapid transit tracks. Shown is one of the platforms, looking south.*



A signal tower *was one of several facilities constructed at Wellington in addition to the Station and Repair Facility. Other structures included a D.C. sub-station and two D.C. circuit breaker houses. Shown here is the signal tower, looking north from the station's control house.*



A Modern Track, Power, Signals and Communications System

The construction of the Haymarket-North Extension included the most modern and efficient systems available during the late 1970's.

The track structure, consisting of 115# continuous welded rail on wood ties and ballast, was installed under three contracts:

1. Haymarket Station to Sullivan Square Station
2. Sullivan Square Station to the terminus at the Malden/Melrose Line, and
3. Wellington Storage Yard and Shop Complex.

The trackwork from Haymarket Station to Sullivan Square Station consisted of a two-track layout through the tunnels and incline approaches with a diamond crossover installed south of North Station. The tracks then diverged into a three-track layout, with one track for express service, south of Community College Station through Sullivan Square Station, with tail tracks and crossovers north of the station. These crossovers were arranged so that Sullivan Square Station could operate as a terminus until the next segment of the line to Wellington was opened for operation.

The second contract continued the installation of the three-track system from Sullivan Square Station to the Oak Grove area in Malden. A system of turnouts and crossovers were installed at each end of Wellington Station and at the entrances to the Wellington Yard Complex. Another set of crossovers, south of Oak Grove Station, was installed for a turnback operation.

The third track from Wellington Station to the Malden/Melrose line was used by the Authority's Commuter Rail system and the Boston & Maine Corporation for local freight trains.

The third contract installed the tracks in the Wellington Yard and Shop Complex. This consisted of 14 yard storage tracks, nine (9) tracks through the repair shop, double loop tracks on the north end of the yard and ladder tracks at the south end.

Once the track had been constructed, the electrical contractors installed the third rail to the track structure and connected it to cables installed in an underground duct system. This duct system was constructed along the right-of-way with terminations at existing and new traction power sub-stations along the route.

Four new sub-stations were constructed at Sullivan Square Station, the Wellington Complex, Malden Center Station, and just north of the terminus at Oak Grove to provide for this and a future extension.

Each sub-station was supplied 13,800 volt AC power by the local utility company.

Within each sub-station, this AC power was converted through a system of transformers and silicone diode rectifiers, into 600 volt DC traction power required to run the cars on the system.

The construction of the Haymarket-North Extension included the installation of a comprehensive, modern system of automatic train control and complete wayside communications. Although the Haymarket-North Project was not the first MBTA Line to feature this system (it was installed in the early 1970's along the new Red Line-South and recently its Northwest Extension from Harvard to Alewife), its inclusion for the Orange Line-North was considered important in the MBTA's effort to provide the highest possible degree of operational safety for its new rapid transit lines. (The relocated Southwest Corridor Project Orange Line between New England Medical Center and Forest Hills also features this system.)

The train control system is comprised of two basic functions:

1. Automatic Train Control (ATC)
2. Automatic Train Operation (ATO)

Under the ATC System, the operation of trains is basically manual, with automatic equipment providing protection against speeds exceeding the limits indicated by the supervisory control functions of a Cab Signal System.

The ATO System of operation utilizes electronically operated automatic equipment to control the starting, acceleration, speed regulation and braking of trains, as governed by curves, grades and distances. Further safety is provided through the interlocking of switches and signals.

In addition, it is also possible to provide remote supervision and control of train operation manually, from the Authority's Operations Center at 45 High Street in Boston.

The Cab Signal System consists of car-borne signal and control equipment, regulated and governed by track and wayside circuitry. It provides supervisory control, which is utilized under both the ATC and ATO systems.

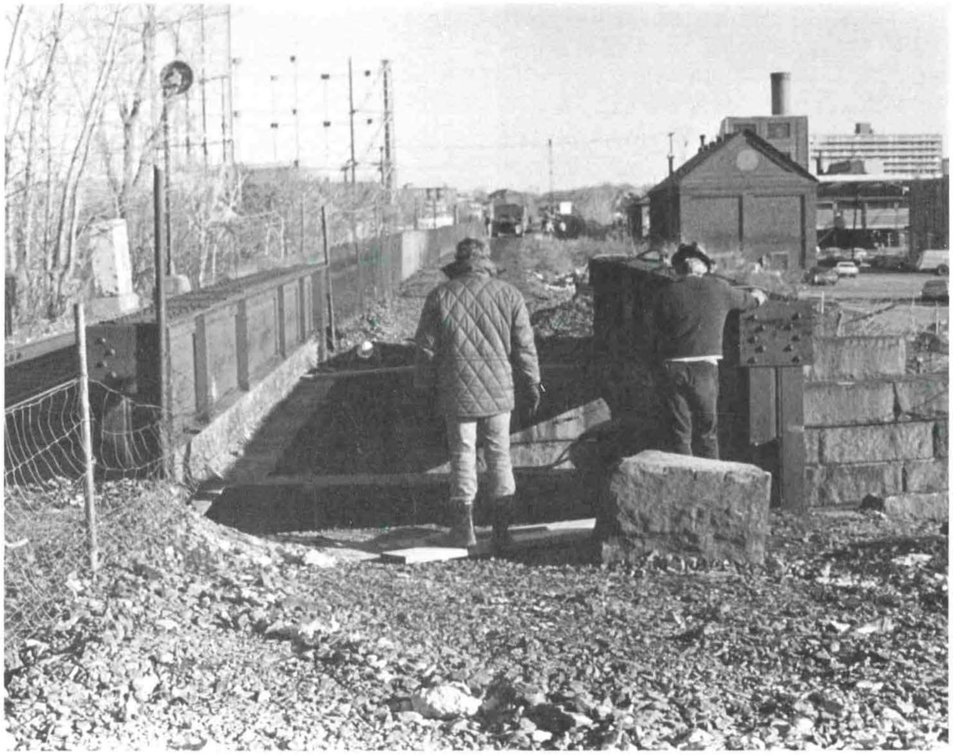
Installation of the System

The Wayside Signal and Communications System was installed between 1973 and 1976 at the High Street Control Center, the Wellington Signal Towers and the new North, Community College, Sullivan Square, Malden Center and Oak Grove Stations.

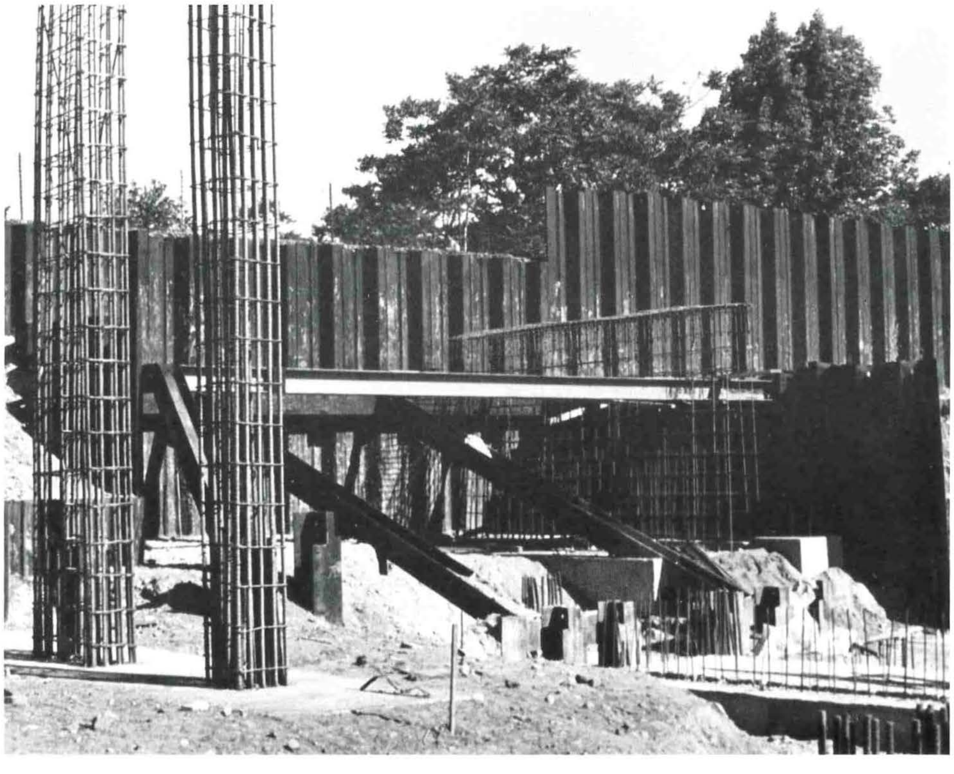
The installation of the permanent signal system, however, was delayed and preceded by installation of a temporary wayside system because the car-borne equipment, required for complete and full automatic operation, could not be installed in the Orange Line cars in time for the Extension's opening. The construction schedule was three to four years ahead of the schedule for the refurbishing of existing cars and receipt of new Orange Line cars, which resulted in the MBTA directing the contractor to install a temporary Auto-Block signal system. This system was installed from the existing system at Haymarket Station, initially to Sullivan Square and later to the Wellington Complex and Oak Grove. The installation of the permanent system was completed in conjunction with the Southwest Corridor.

Malden Center Station and Bridges

Malden Center Station was constructed in conjunction with the reconstruction of four bridges over Malden streets and the construction of a new bridge over the later relocated Route 60 in Malden. Awarded in November of 1973 and completed by late 1975, this contract covered approximately 6,600 feet of trackbed and included the installation of all the fencing along the Extension's entire right-of-way and installation of the rapid transit track from Sullivan Square to the Malden/Melrose Line. (Track installation from north of Haymarket Station to Sullivan Square was installed under a separate contract, including two rapid transit tracks from Haymarket to just south of Community College Station and three rapid transit tracks, one for express service, from Community College to Sullivan Square Station. In addition, a single railroad track was installed over the easterly span of the Edward Dana Bridge.)



Alignment of the Extension through Malden required the ***reconstruction of four bridges*** *over existing streets, including this one at Medford Street. The others are located over Adams, Charles and Pleasant Streets.*

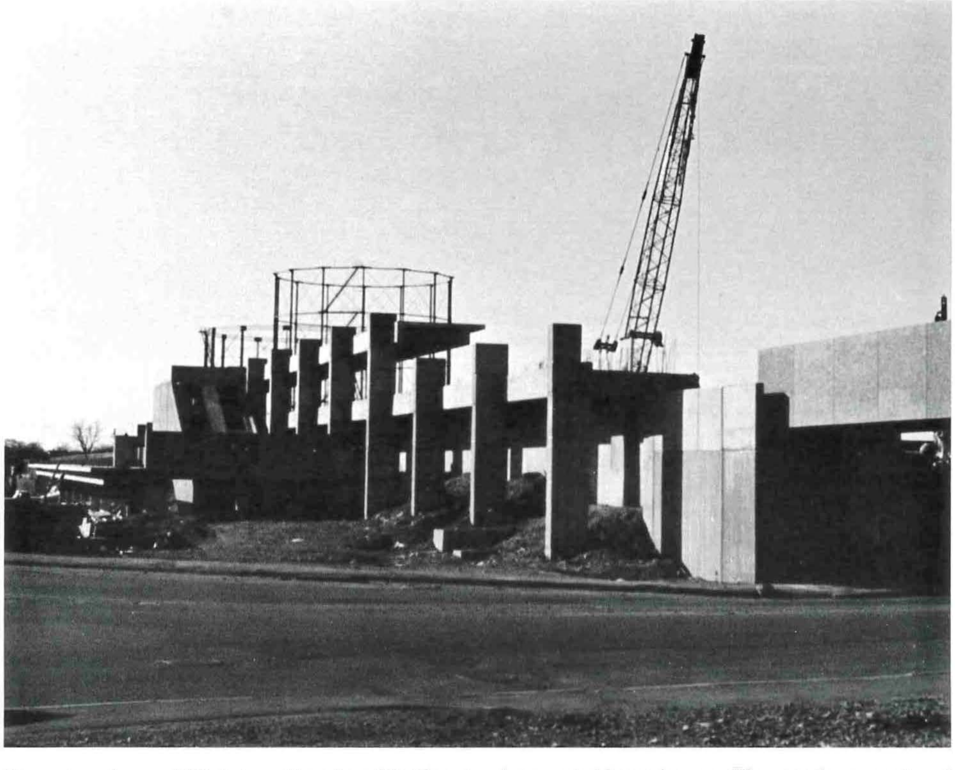


Malden Center Station *was constructed west of Malden Square, at the intersection of Pleasant and Commercial Streets. The station's foundation of structural steel piles, bracing and cast-in-place concrete, is shown here.*

The Extension through Malden required extensive construction and reconstruction of bridges to accommodate the three new Orange Line tracks and provide trackage to permit continued railroad operation. These included bridges over Medford, Adams, Charles and Pleasant Streets.

The reconstruction of these four bridges, as much of the bridge work accomplished as part of the Extension, required scheduling and coordination to meet the requirement that construction would not interfere with railroad service. As a result, it was necessary to restrict work to half the width of each bridge at a time to permit a single track operation for railroad commuter lines and freight service. Activities to strengthen the bridges prior to construction included the driving of steel sheeting into the abutments, in order to maintain railroad service.

*View of the nearly-completed commuter rail **platform** for Malden Center Station.*



*The structure of **Malden Center Station** is shown taking shape. The station contract included the construction of two main busways, kiss-and-ride drive area, auxiliary busway and driveway and parking lot for 148 cars. It also included the foundation and related preparation for a pedestrian passageway between the station to the plaza area of the Malden City Hall, which is still planned for construction by others in the future.*

Malden Center Station

While bridge work continued, the contractor began preparing the site and driving piles for the new Malden Center Station, which was constructed west of Malden Square, at the intersection of Pleasant and Commercial Streets near the Malden Government Center. Similar to other surface Haymarket-North stations, this is a two-platform, three-track station, constructed of concrete, using both pre-cast and conventional cast-in-place methods. It consists of a two-level facility with escalators and stairways providing access between the lower level fare collection area and platforms on the upper levels.

The contract for this station included the construction of a parking area for 148 cars, accessible from both Pleasant Street and the relocated Route 60; two main busways and a kiss-and-ride area on Commercial Street; and an auxiliary busway and driveway on the west parking lot side.

The construction of several entrances was included, as well as the preliminary work for an enclosed pedestrian passageway from the station over Commercial Street, to the plaza area of Malden City Hall. Although this passageway will be completed later by others, certain elements of its construction, including foundations, elevator pits and the stairwell from the platforms, were incorporated into the Malden Center Station contract.

Malden Center Station was opened for service on December 27, 1975.

Throughout its alignment, the Extension was constructed ***over, under and alongside*** *active railroad lines, as was the case in this view of construction between Malden Center and Oak Grove Stations.*

Close proximity *of active railroad lines to Extension construction continually required that provisions be made to keep rail service, as shown here between Malden Center and Oak Grove Stations, operational.*

Oak Grove Station

The contract for the construction of Oak Grove Station and related rapid transit facilities commenced on October 23, 1974 and was completed in early 1977. The station opened for service on March 19, 1977.

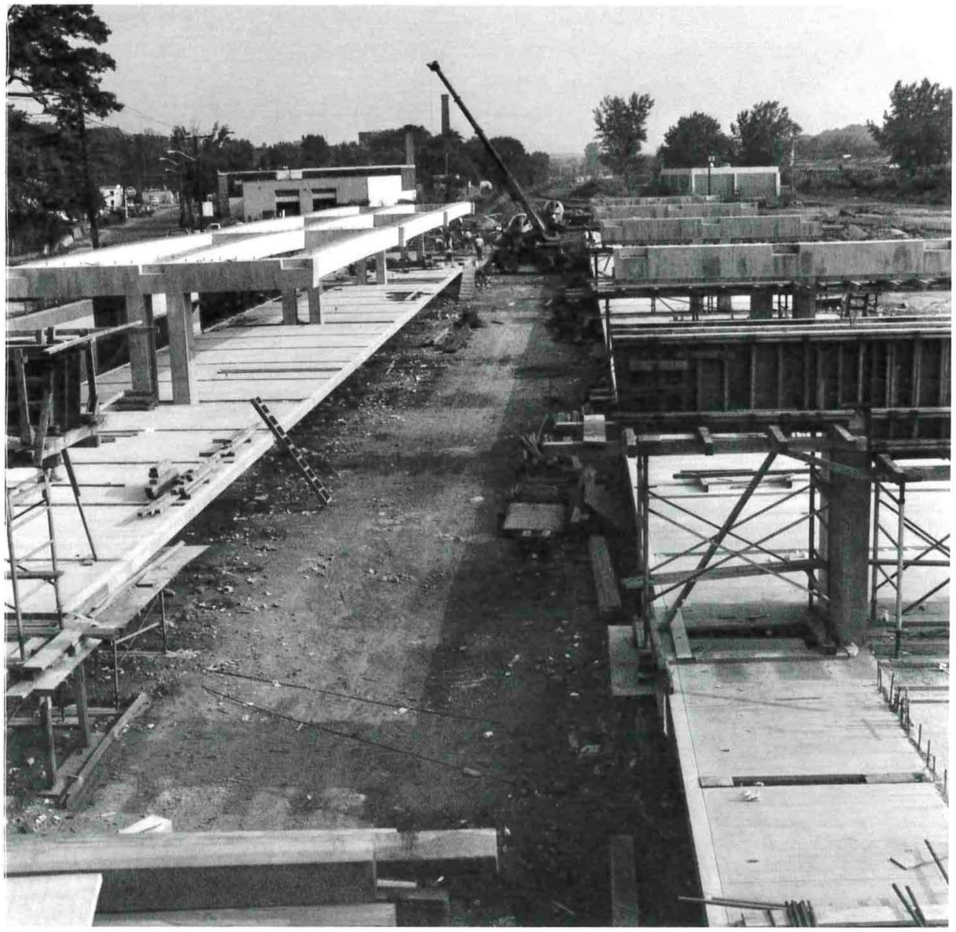
Oak Grove Station, the final station and terminus for the Haymarket-North Extension, was constructed near the Malden/Melrose City Line, approximately 3/4 miles north of Malden Center and immediately north of Winter Street. A new Winter Street Bridge was constructed under a separate contract during 1975 and 1976 to eliminate the Winter Street grade crossing.

The Oak Grove Station is accessible from both the east and west sides of the station. On the east side, an access road extending from Winter Street to Banks Place in Melrose was constructed to permit through operation of buses from both ends to a busway at the station. Parking facilities for approximately 500 cars were provided, as well as drop-off and pick-up area for 28 cars. A similar area for 39 cars, in addition to a bus stop connection, was provided on the west side of the station at Washington Street, near Winter Street.

Station construction included entrances to the station from both the Washington Street and the Access Road areas, with escalators and stairways to the upper level lobby to the fare collection facilities. Other escalators and stairways provided connection to the train platforms at the lower level. Elevators on each side of the station also were constructed to provide accessibility for handicapped and elderly persons.

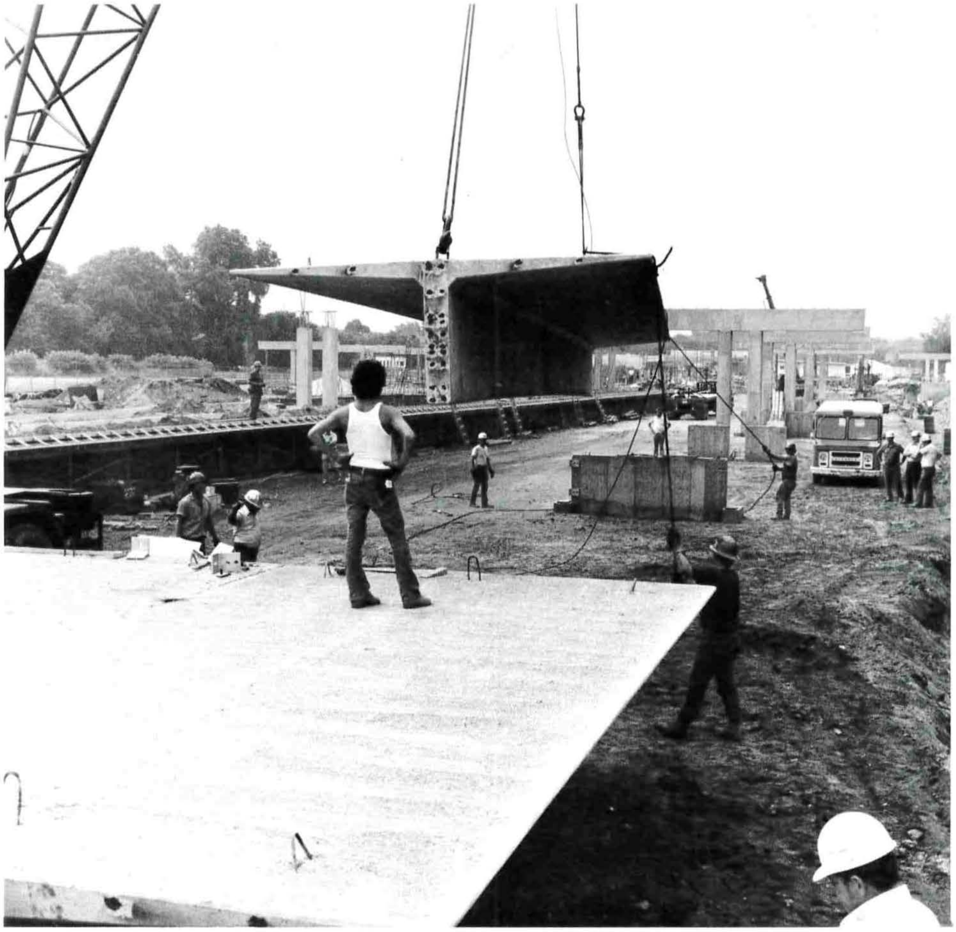
The station structure was constructed almost entirely of concrete, including pre-cast and pre-stressed members as well as conventional cast-in-place concrete. Design features provided for the extensive use of both rough-board and smooth concrete finish, as well as brickwork, block masonry, and ceramic veneer. In addition, the work included landscaping and the installation of clerestory windows, continuous skylights and plastic glazing to highlight the main entrances on the lower level and the escalators and stairways to the upper platform level.

As with other Haymarket-North contracts, the construction of Malden Center and Oak Grove Stations was affected by some of the reoccurring problems that resulted in delays. Labor strikes resulted in delays of more than 85 days during the construction of Malden Center. The later construction of Oak Grove was impacted less.

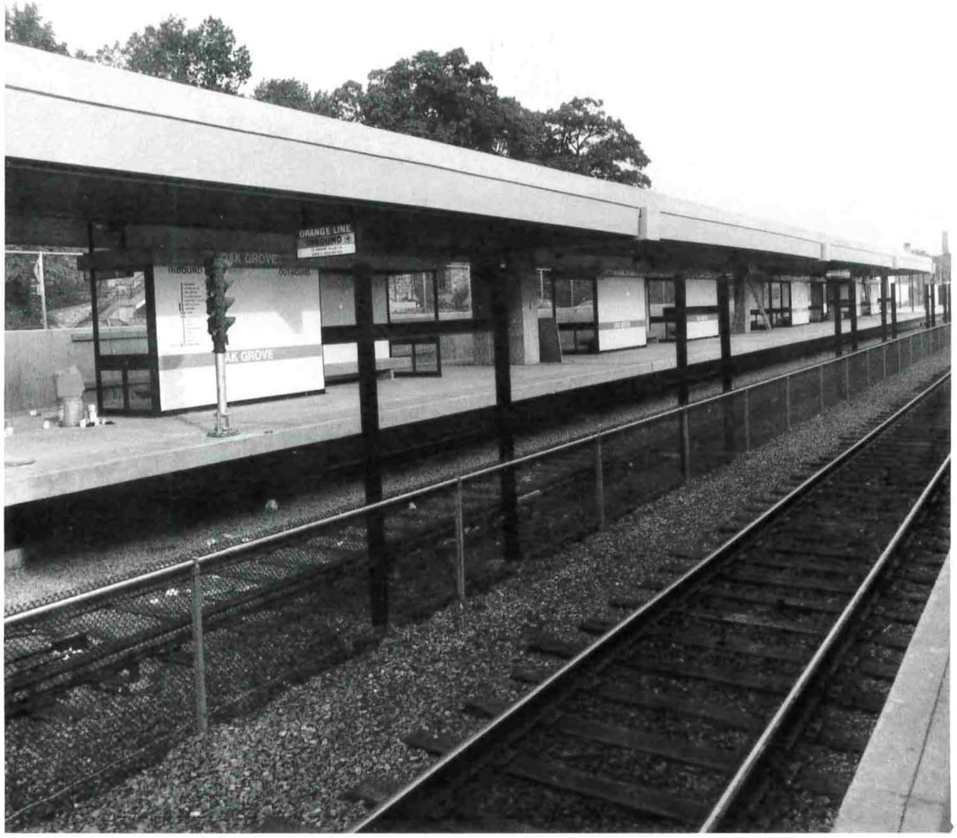


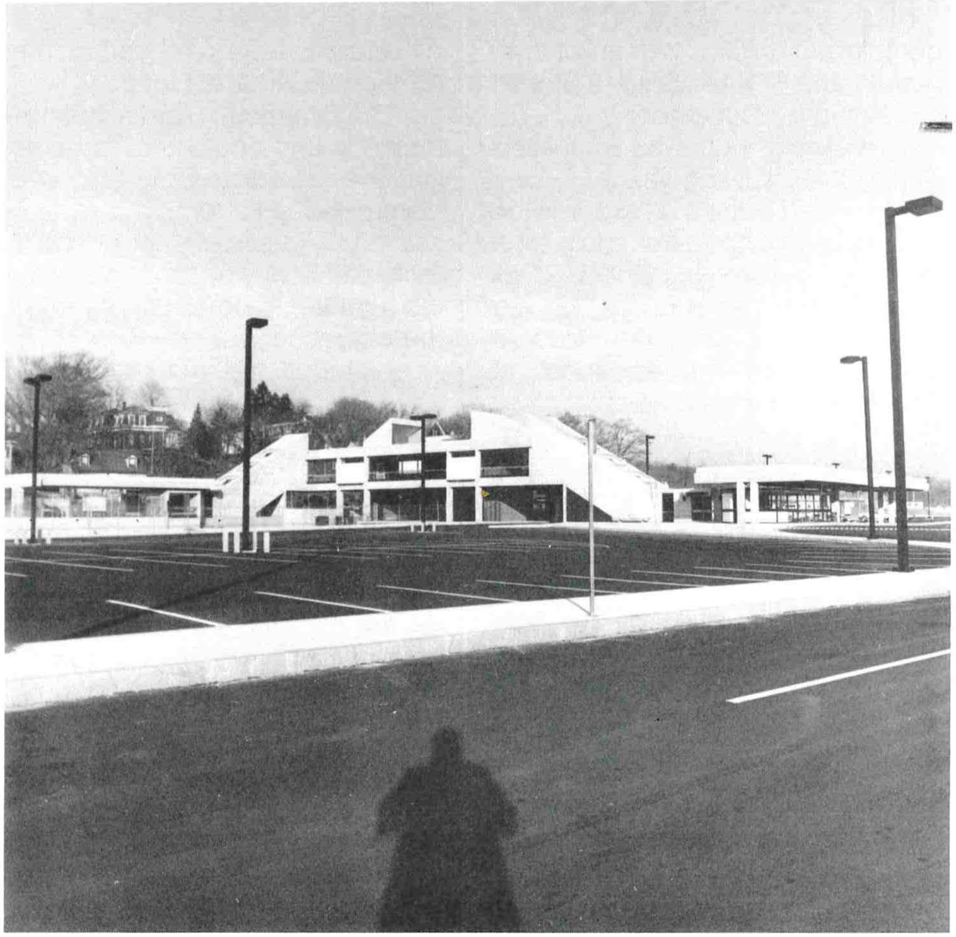
Oak Grove Station *was constructed immediately north of Winter Street in Malden, just south of the Malden/Melrose line. Shown is the station area, looking north from the lobby floor, during its construction in 1975. During construction, the railroad was relocated to the east of the site.*

Structure of ***Oak Grove Station*** *consists almost entirely of concrete construction, including pre-cast and pre-stressed members as well as conventional cast-in-place concrete. Pictured is activity related to the erection of the pre-cast concrete T section for the west platform.*



View of the completed ***inbound platform*** *and both tracks for Oak Grove Station during the fall of 1976.*





Street level view of ***Oak Grove Station*** *facility in December 1976.*

Oak Grove Station*, looking north on Washington Street.*

Demolition of the Elevated Structure

The most publicized contract of the Haymarket-North Extension was the demolition of the 74-year-old elevated structure from the Haymarket area in downtown Boston to Everett, following the opening of service along the new line to Sullivan Square Station. Strongly welcomed by representatives and residents of the communities along the alignment of the old structure, the demolition was considered a major step toward neighborhood revitalization and, according to area newspapers, was referred to as the "destruction of that black serpent of blight."

The commencement of the work was marked by a launching ceremony in City Square on August 21, 1975, which was attended by more than 500 persons, many of whom broke champagne bottles against the structure's steel girders to demonstrate their approval.

The demolition activity was accomplished quickly, with only North Station and Sullivan Square Station remaining by December 31, 1975. The remaining work was completed during the following year.

Included in the contract was the removal and disposal of: the station structures at North Station, City Square, Thompson Square, Sullivan Square, and Everett; the elevated structure from the abutment at Traverse Street in Boston to Everett Station in Everett; the overhead yard facilities at Sullivan Square, the superstructure of the bridge over the Mystic River between Somerville and Medford; the elevated structure from the superstructure of the Charlestown Bridge; as well as all other related structures, track, including the third rail, ties, switches, cables and other power lines. The contract specified that all streets and sidewalks, removed during demolition, were to be restored where required. All columns were removed to three (3) feet below street level.

The contractor used a variety of methods and equipment to demolish the structures, which were dismantled and removed in large sections. An assortment of special tools and heavy equipment, including a 50-ton hydraulic crane, aided the operation.

Although the work proceeded without major problems, this activity, as other construction associated with Haymarket-North, was subject to the economic conditions and issues of the 1970's. This included Boston's School Busing Crisis, which created a shortage of police officers available for the required traffic control and safety details. The situation resulted in the MBTA Construction Directorate using its own employees to help perform these critical safety functions.

Conclusion

In the decade since the construction of the Haymarket-North Extension, the MBTA has accomplished several other major construction efforts. These are the 3-mile Red Line Extension from Quincy to Braintree; the 3.2-mile Red Line Northwest Extension from Harvard Square to Alewife Brook Parkway in Cambridge; and the recently opened 4.7-mile Southwest Corridor Project from downtown Boston to Forest Hills in Jamaica Plain. In addition, the MBTA completed the speedy reconstruction of two vital commuter rail bridges, at North Station and the Beverly-Salem line, following tragic fires that destroyed the structures and paralyzed commuter rail service on several heavily-traveled lines.

These projects presented many challenges for the MBTA and required ability and expertise as well as a heavy reliance upon past experience to deal effectively and successfully with the numerous engineering, construction, coordination and scheduling complexities they posed.

As described in the preceding pages, the Haymarket-North Extension provided a real training ground that enabled the MBTA to meet the challenges of later years. In addition to the numerous engineering difficulties involved during the construction of this Extension, the Authority entered into nine (9) separate Force Account agreements with the Boston & Maine Railroad and the time entailed in negotiating an agreement ranged anywhere from 9 months to 18 months.

In conclusion, this project clearly demonstrates the varied and complex character of the work that was undertaken for the Haymarket-North Extension. This project, in no way, can be considered in the same class of work as highways, airports, buildings, dams, or other types of construction which are less complicated.

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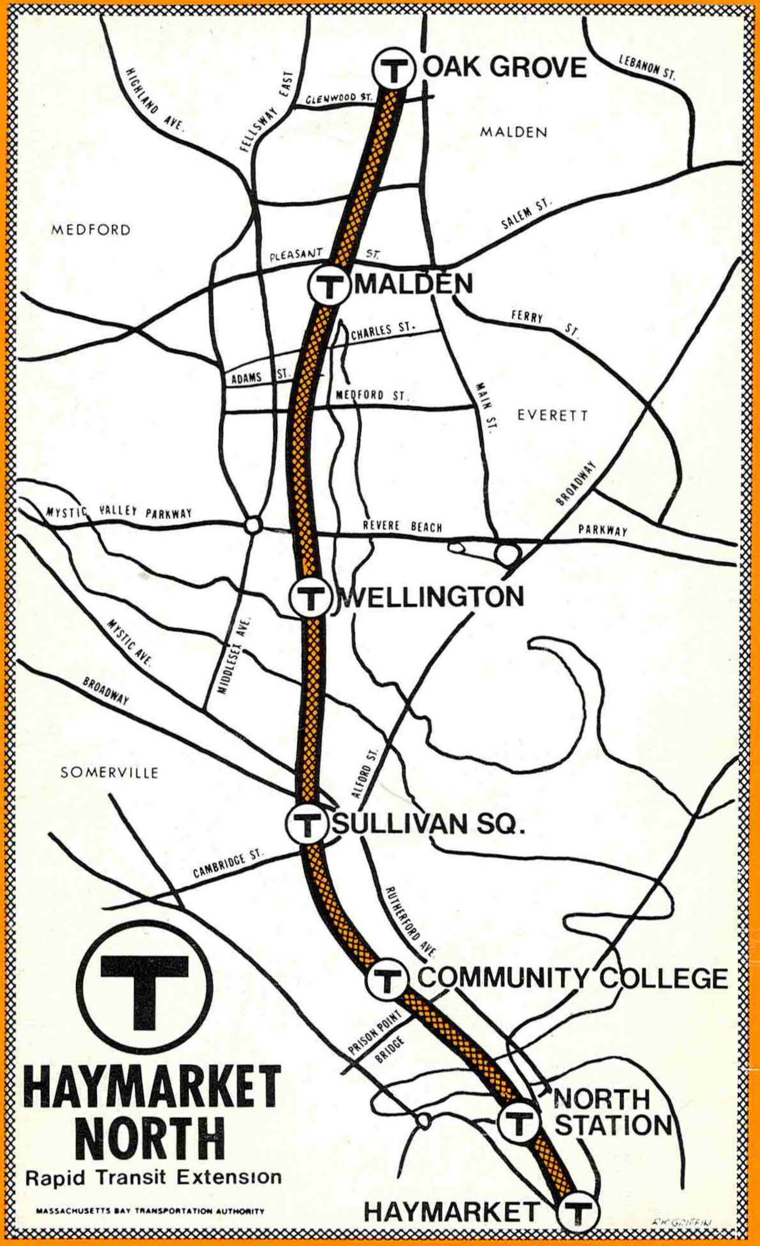
is MBTA Director of Construction and has overall responsibility for the MBTA's $4 billion construction program. A graduate of Northeastern University with degrees in civil engineering and science, Mr. Keville has 35 years of experience in the construction field. This has included projects for railroads and transit systems, airports, power plants, tunnels, bridges, roadways and buildings. During his 20 years with the Massachusetts Bay Transportation Authority, Mr. Keville was directly responsible for the management of the Haymarket-North Extension Project and the Red Line Northwest Extension Project (Harvard Square to Alewife Brook Parkway in Cambridge and Somerville, MA). He has served as Director of Construction since 1981.

Construction Photographs by James E. Miller



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